$\Lambda(1405)_{pn}$ at J-PARC

F. Sakuma, RIKEN

on behalf of the J-PARC E15 collaboration

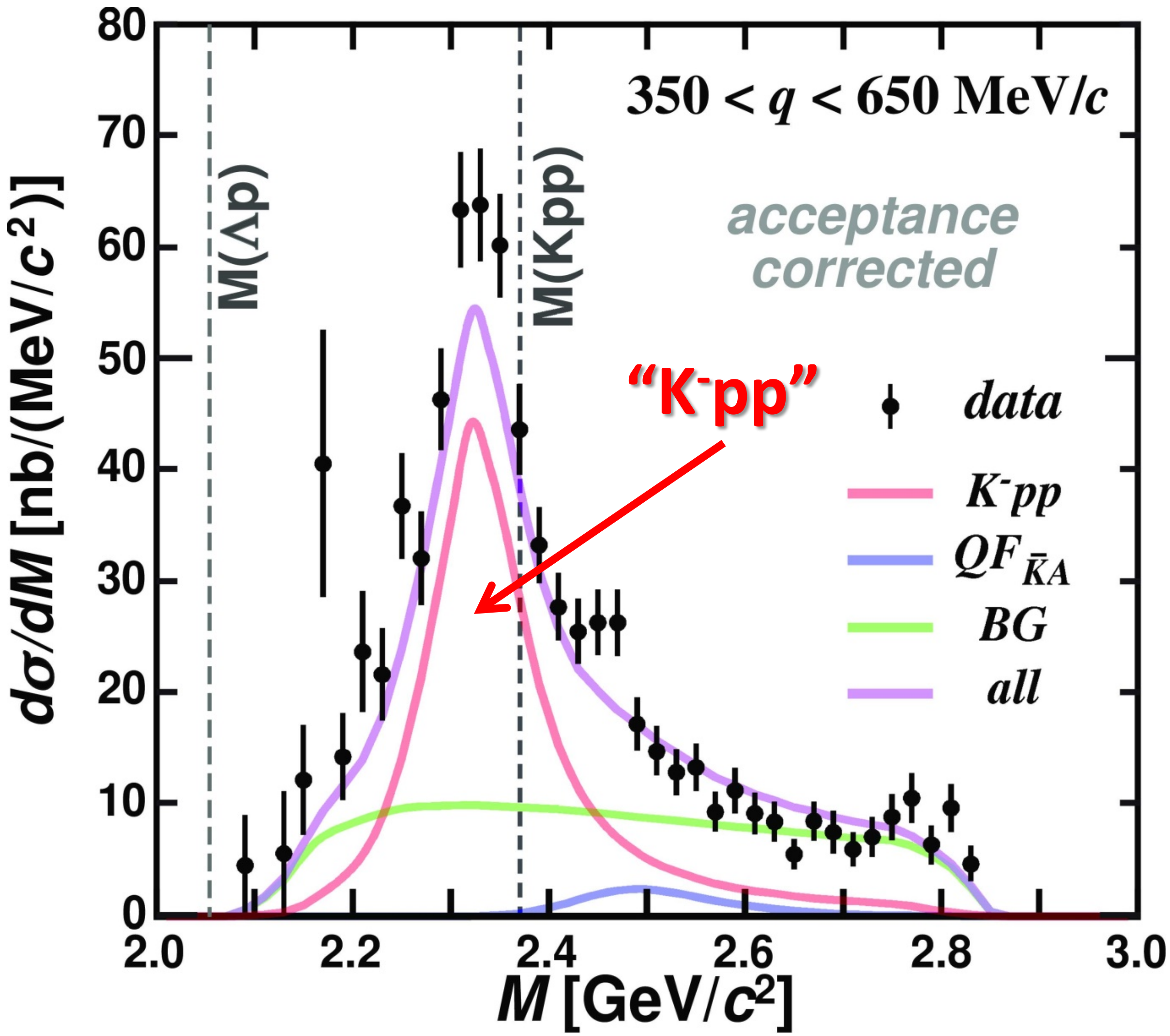
“Strange Matter Workshop - Strangeness studies in Italy and Japan“

Laboratori Nazionali di Frascati INFN

16-17 October 2019

We observed the “K⁻pp” Bound-State

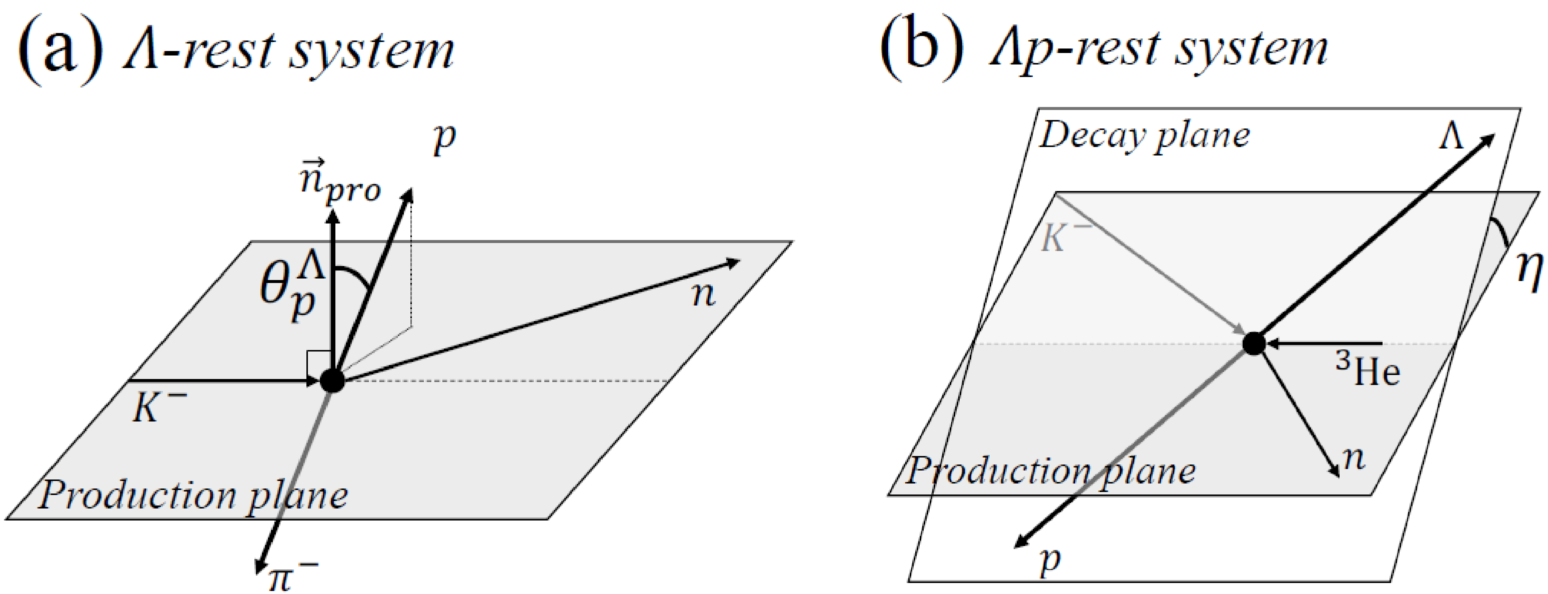
PLB789(2019)620.



We need further understanding

- **Spin/Parity of the "K⁻pp"**
  - *New 4π detector system is needed* **← Future plan**

decay-angle measurement



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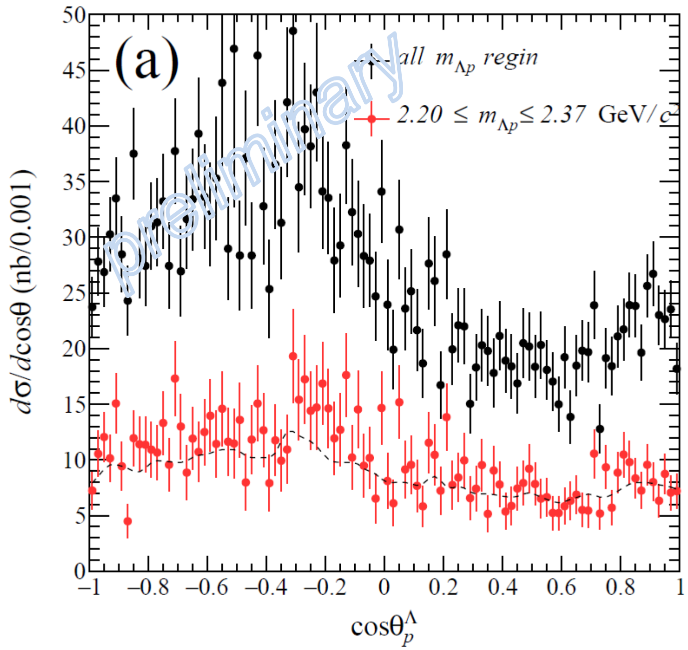
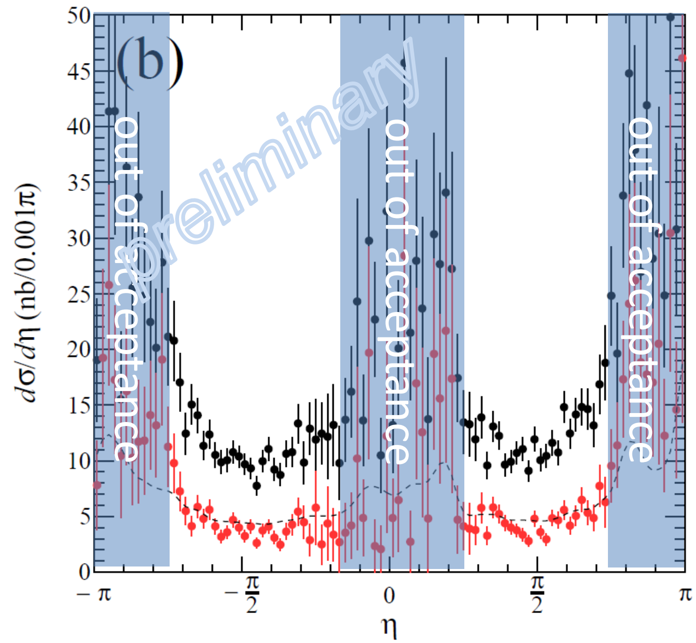
Recent results of the decay-angle measurement is consistent with J=0





Paper in preparation

We need further understanding

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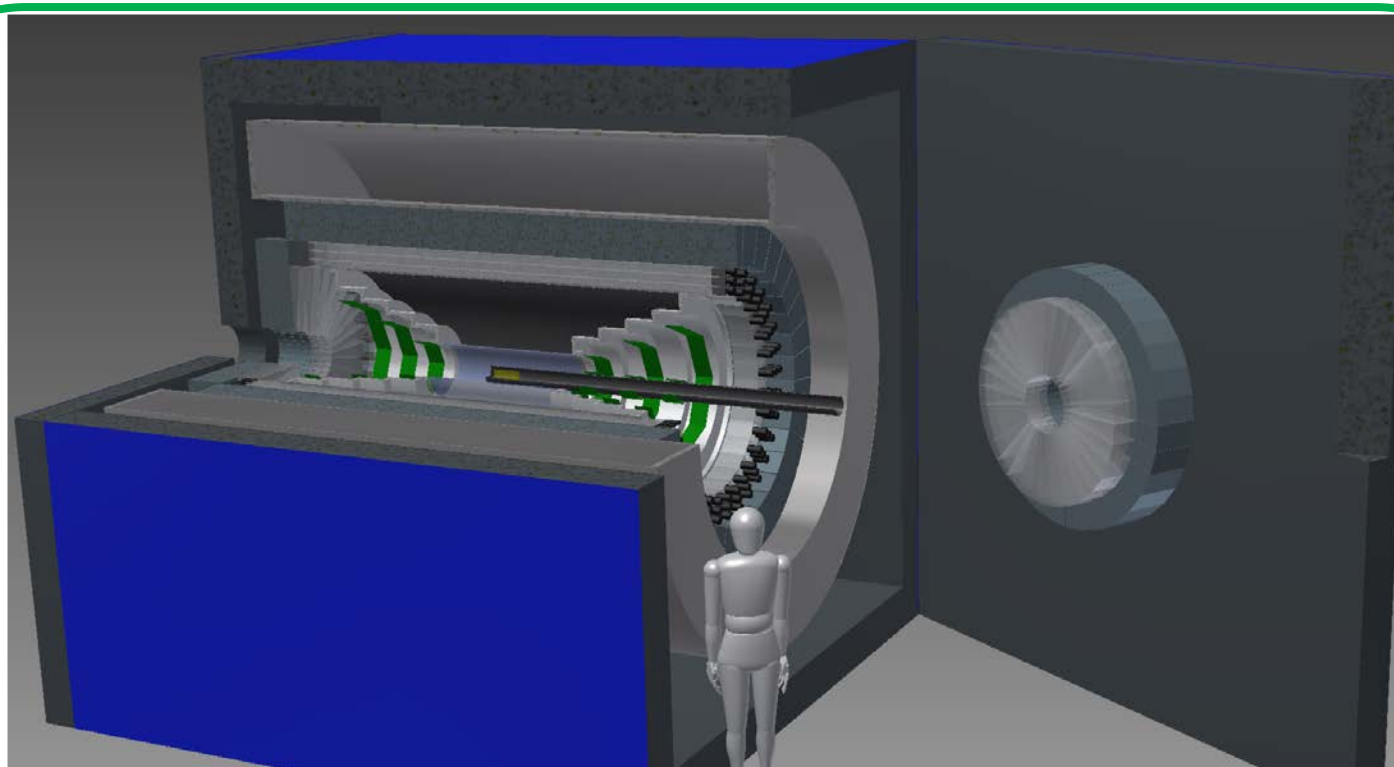

A new 4π detector with γ/n sensitive detectors

We need further understanding

- Spin/Parity of the “K⁻pp”
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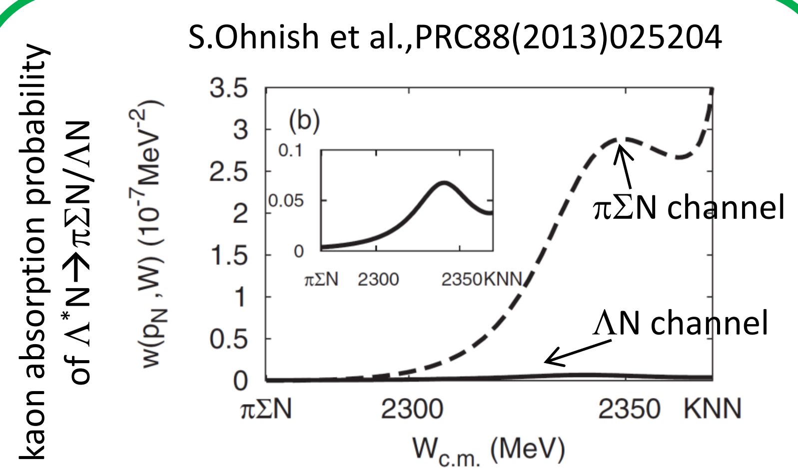
- **Other decay channels**
  - **<u>$\pi\Sigma N$ mesonic decay</u>** is theoretically expected to be the dominant channel
    - Only YN non-mesonic decays were reported



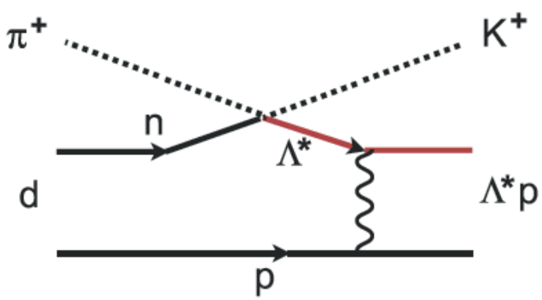
We need further understanding

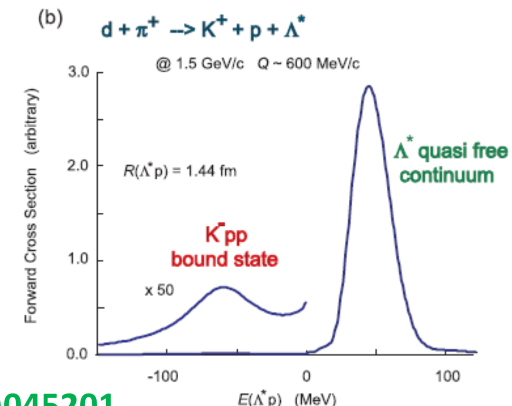
- Spin/
  - *Nev* *e plan*
- Othe
  - $\pi\Sigma$ d to be the
    - C

π^+ + "n" --> "Λ*" + K^+

"Λ*" + "p" --> bound K^-pp ***minor***

--> quasi-free Λ* ***dominant***





Yamazaki & Akaishi, PRC76(2007)045201.

- **Reaction mechanism**
  - Relation between **Λ(1405)** & "K^-pp"
    - Λ(1405) has been considered as **"K^-p"**
    - Theoretically, "K^-pp" is expected to be produced via **Λ(1405)+p→"K^-pp" door-way process**

We need further understanding

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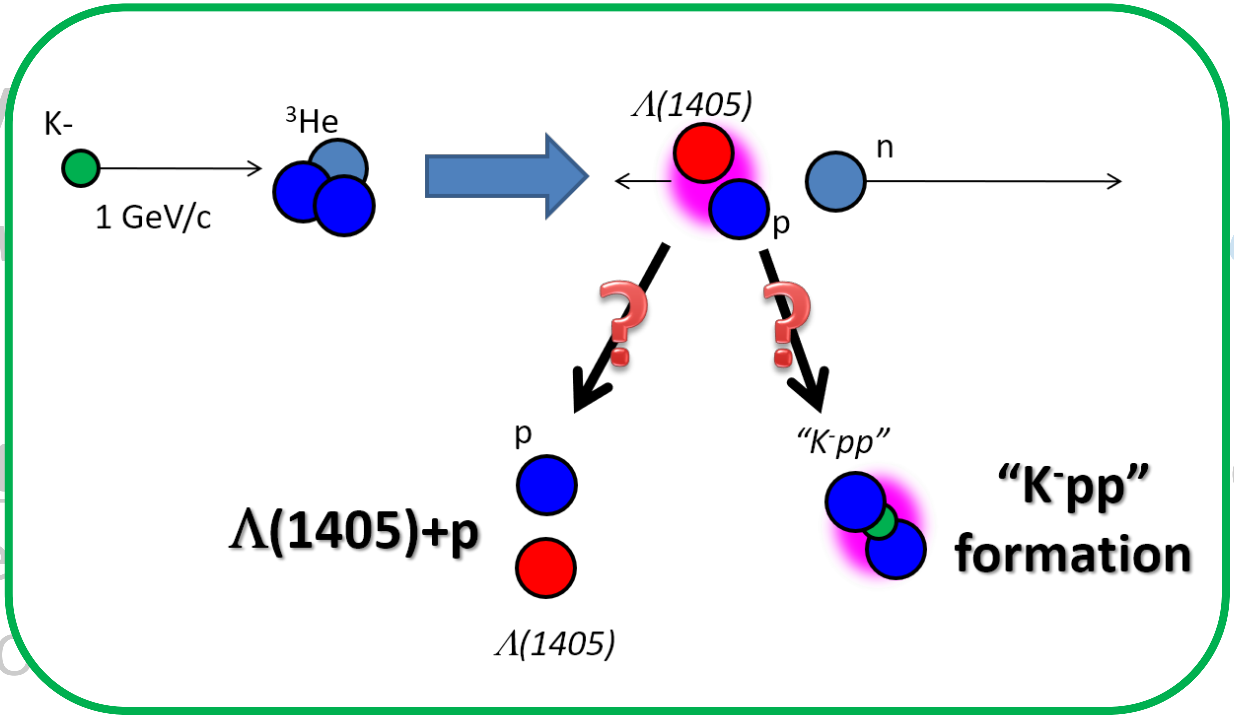

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We need further understanding

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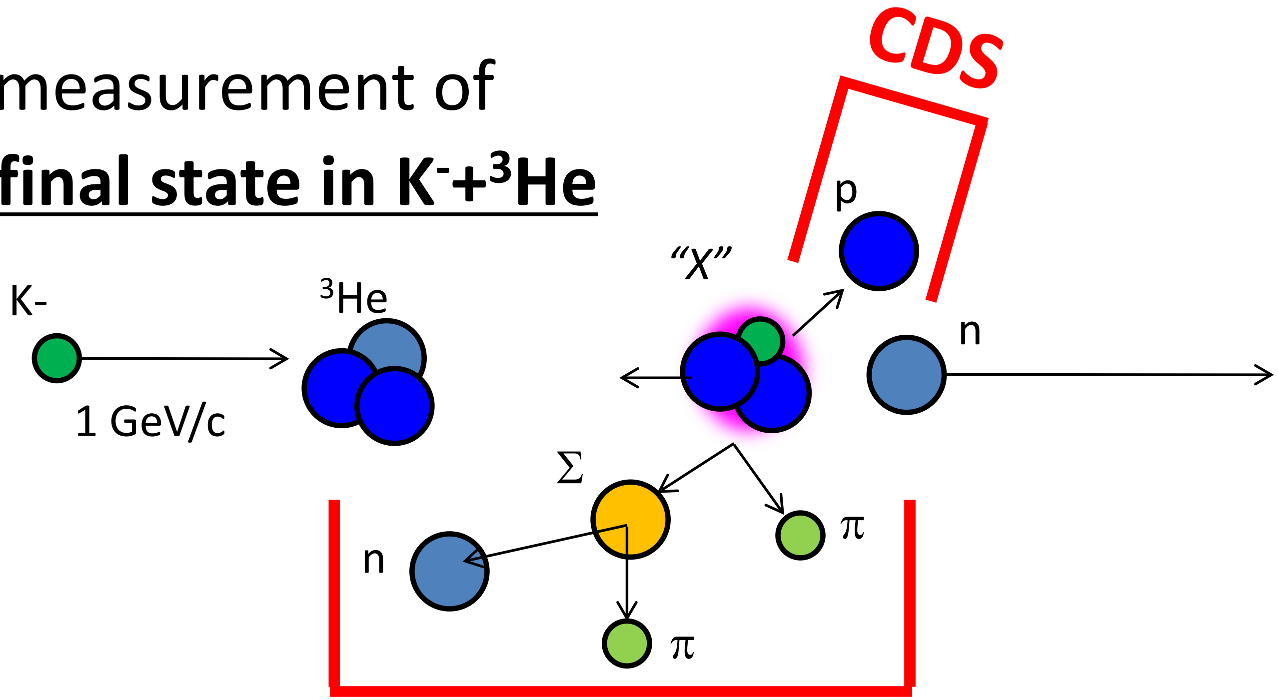
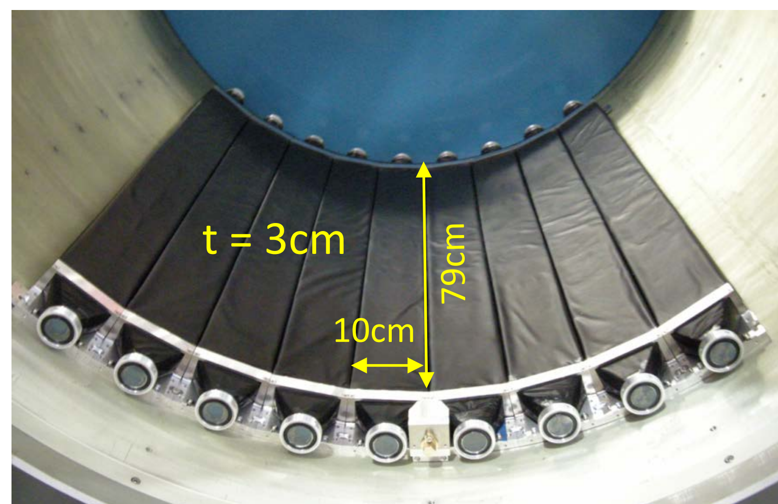
K^- 3He → $\pi\Sigma pn$ @ E15

$K^- \, {}^3He \rightarrow \pi\Sigma pn$ Measurement

- Exclusive measurement of
  $\pi^{\pm}\Sigma^{\mp}pn$ final state in $K^-+{}^3He$



CDS



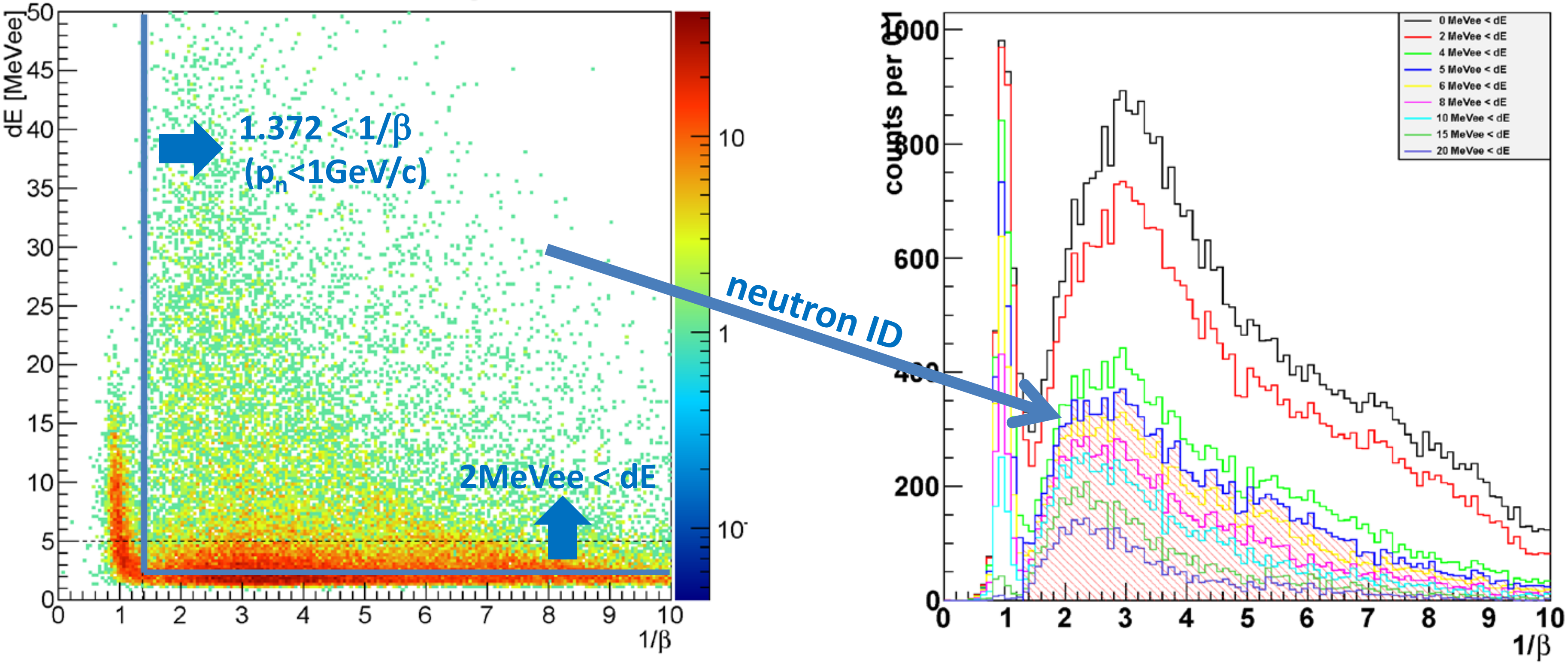
- **Experimental challenge** of neutron detection with thin scintillation counter (t=3cm)

  n detection efficiency ~ 3-10%

Neutron ID with CDS

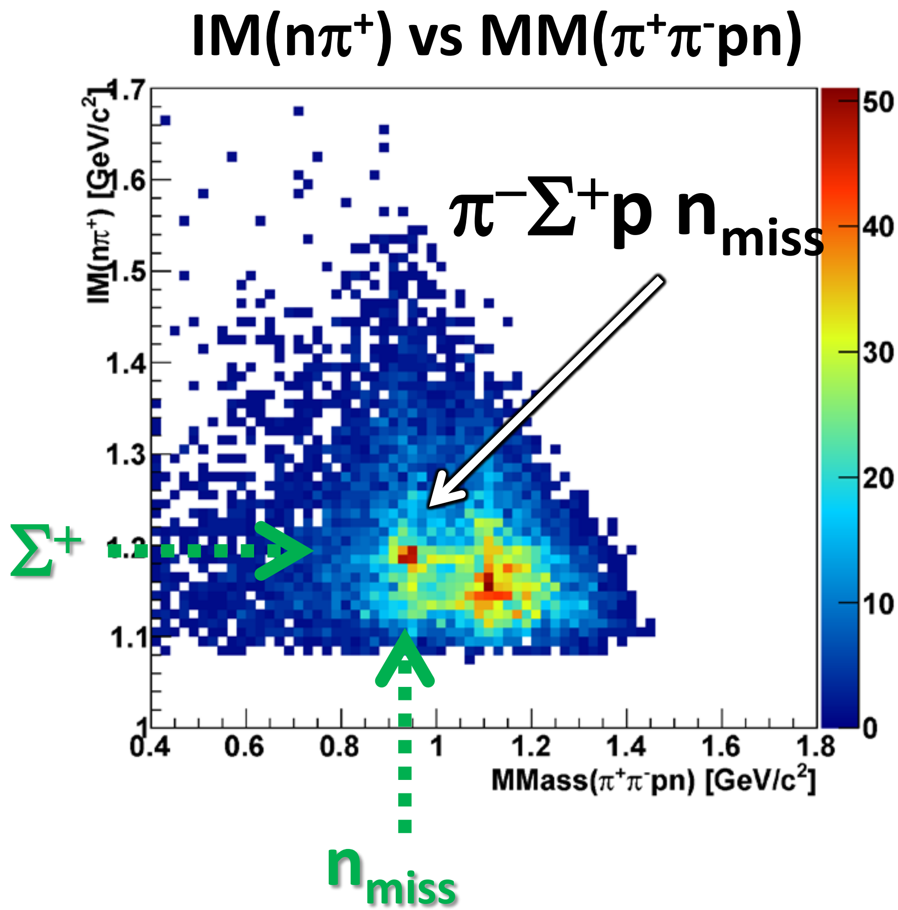
- $\pi^+\pi^-p$ events (3 tracks) in CDS with 4 CDH hits are selected
- a CDH hit with CDC-veto (outer-layer) is applied to identify the "neutral hit"

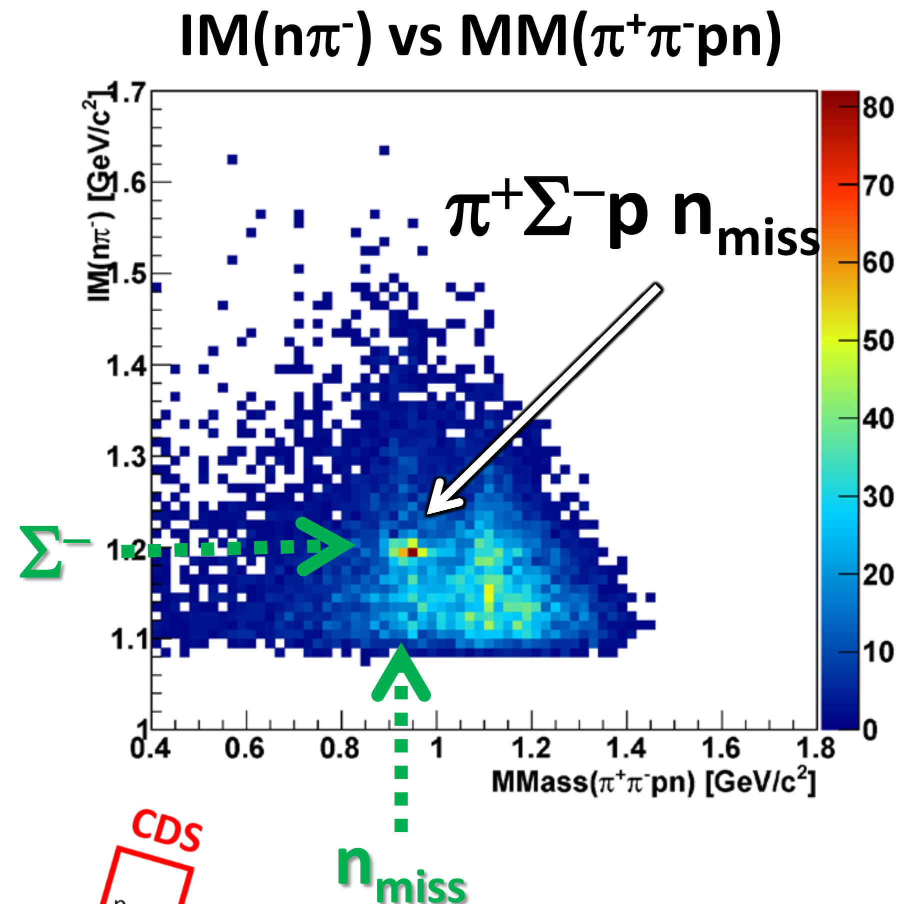
dE vs. 1/β | **dE-cut dependence**

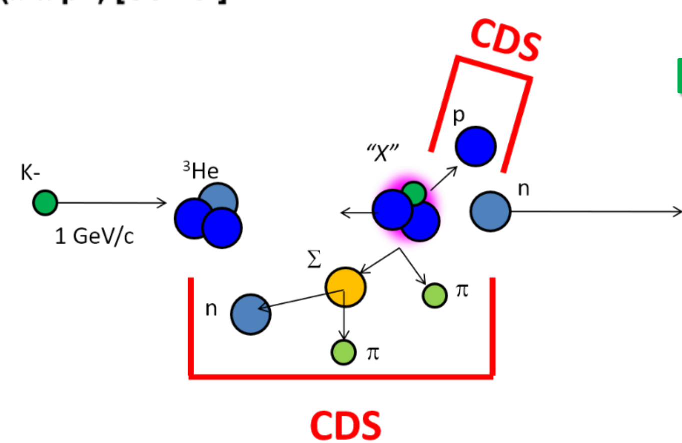


Neutron can be identified with CDS

$\pi\Sigma pn$ Events

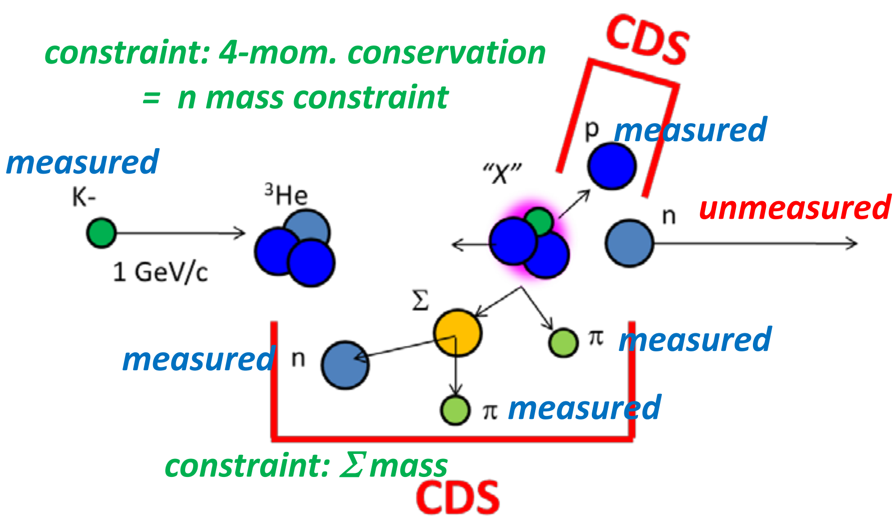




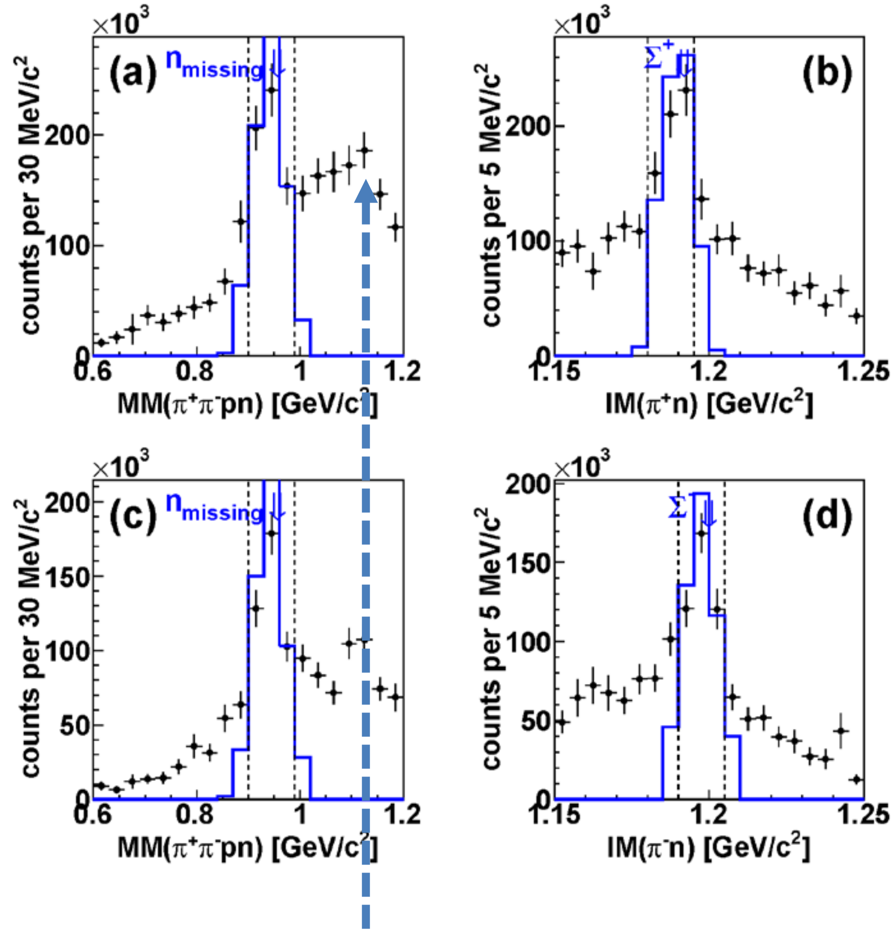


Selection of $\pi^{\pm}\Sigma^{\mp}pn$ Final State

- $\pi^{\pm}\Sigma^{\mp}$ events are separated using kinematical-fit
  - Constraints:
    - M(Σ→nπ)
    - 4-momentum conservation
  - Event selection by χ^2 probability (0.01<p)



e.g. after acc/eff correction



$\pi\pi pn\Lambda/\Sigma^0$ contribution can be seen

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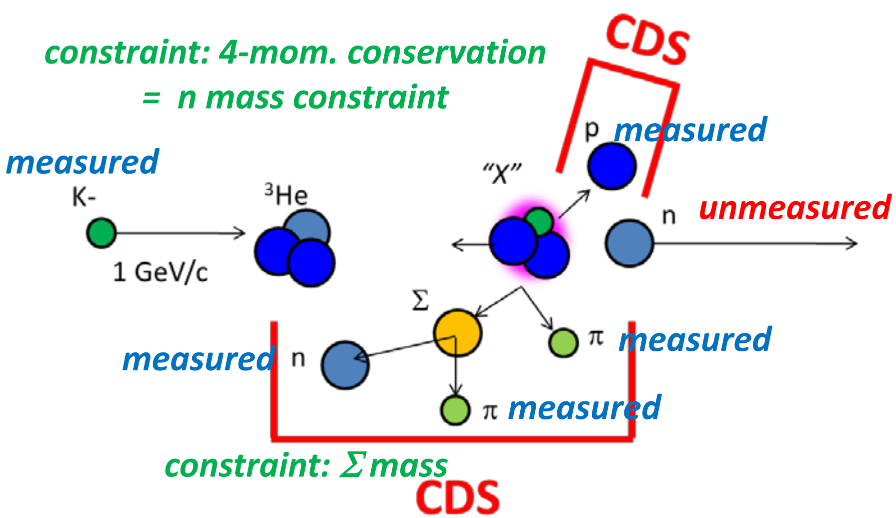

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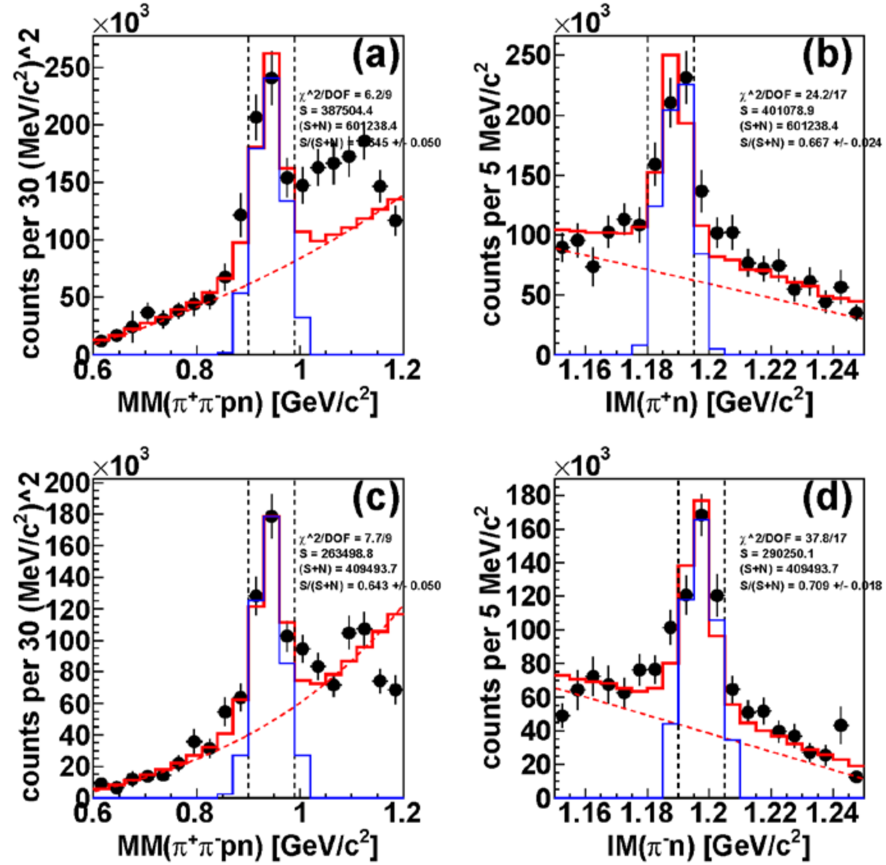

simple BG evaluation & subtraction

Selection of $\pi^{\pm}\Sigma^{\mp}pn$ Final State

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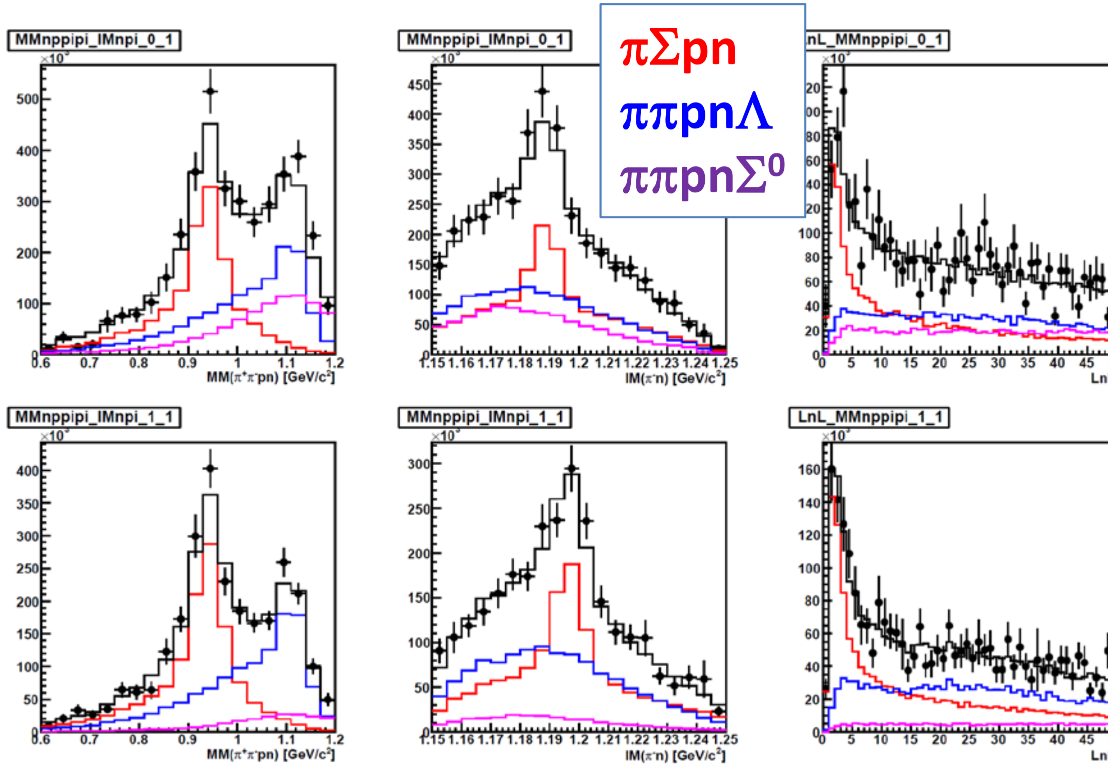
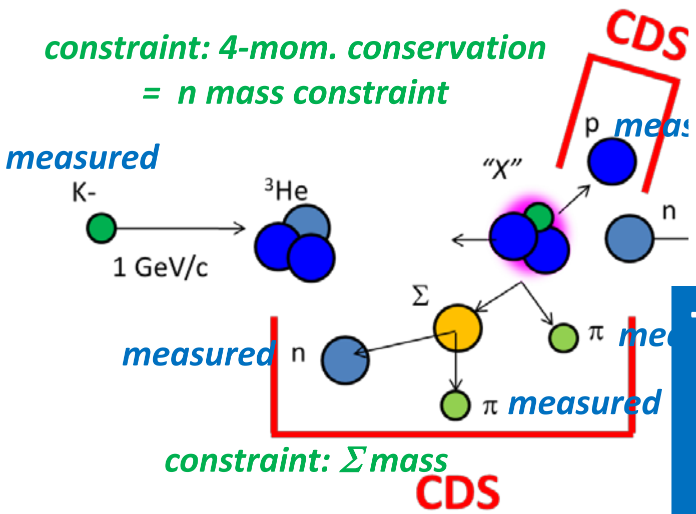
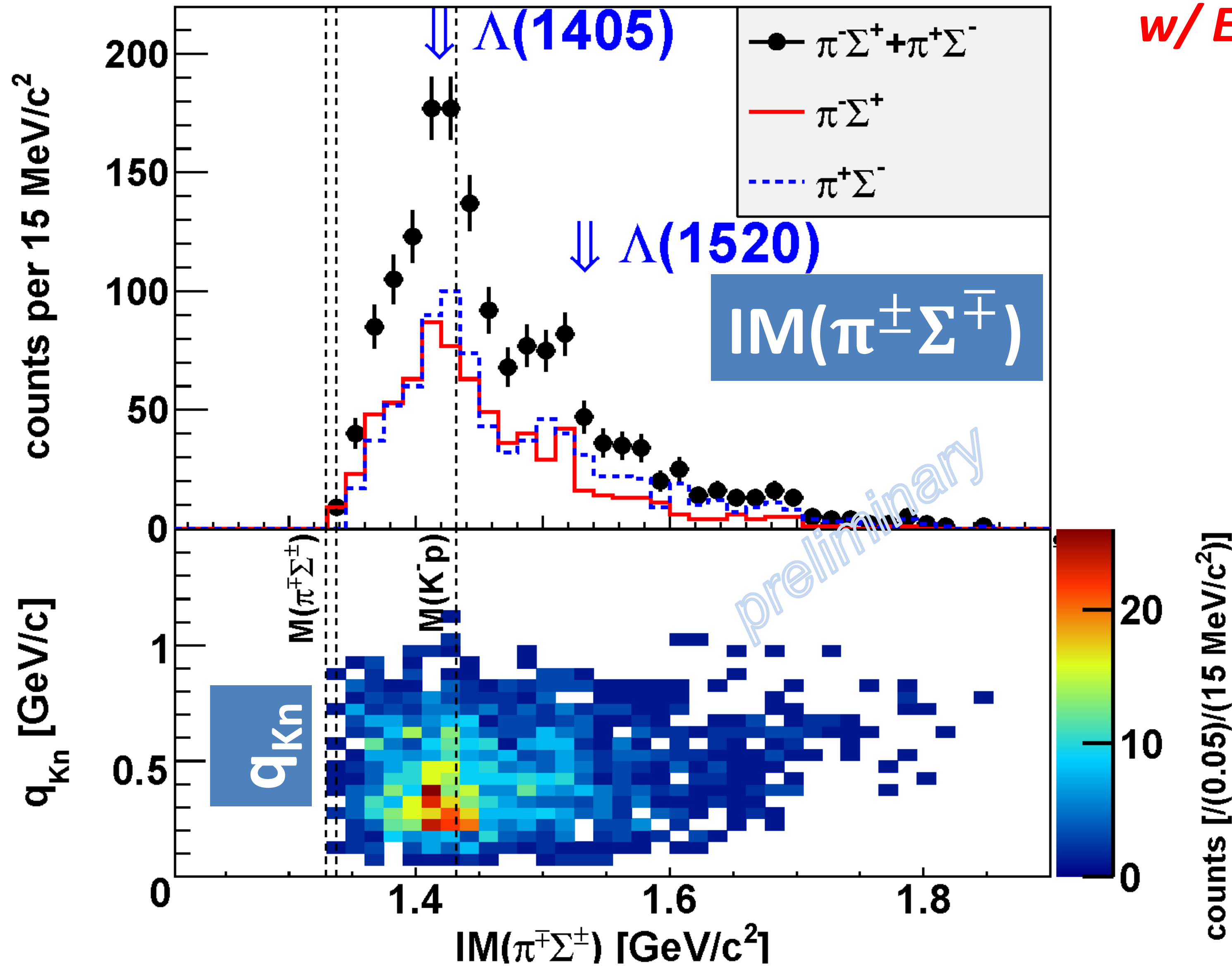




Trying to improve Exp. BG evaluation by introducing
- **new analysis cuts**
- **loglikelihood function with DCA**
- **global fit with signal & BG's**

IM($\pi^{\pm}\Sigma^{\mp}$) in $\pi^{\pm}\Sigma^{\mp}pn$ Final State

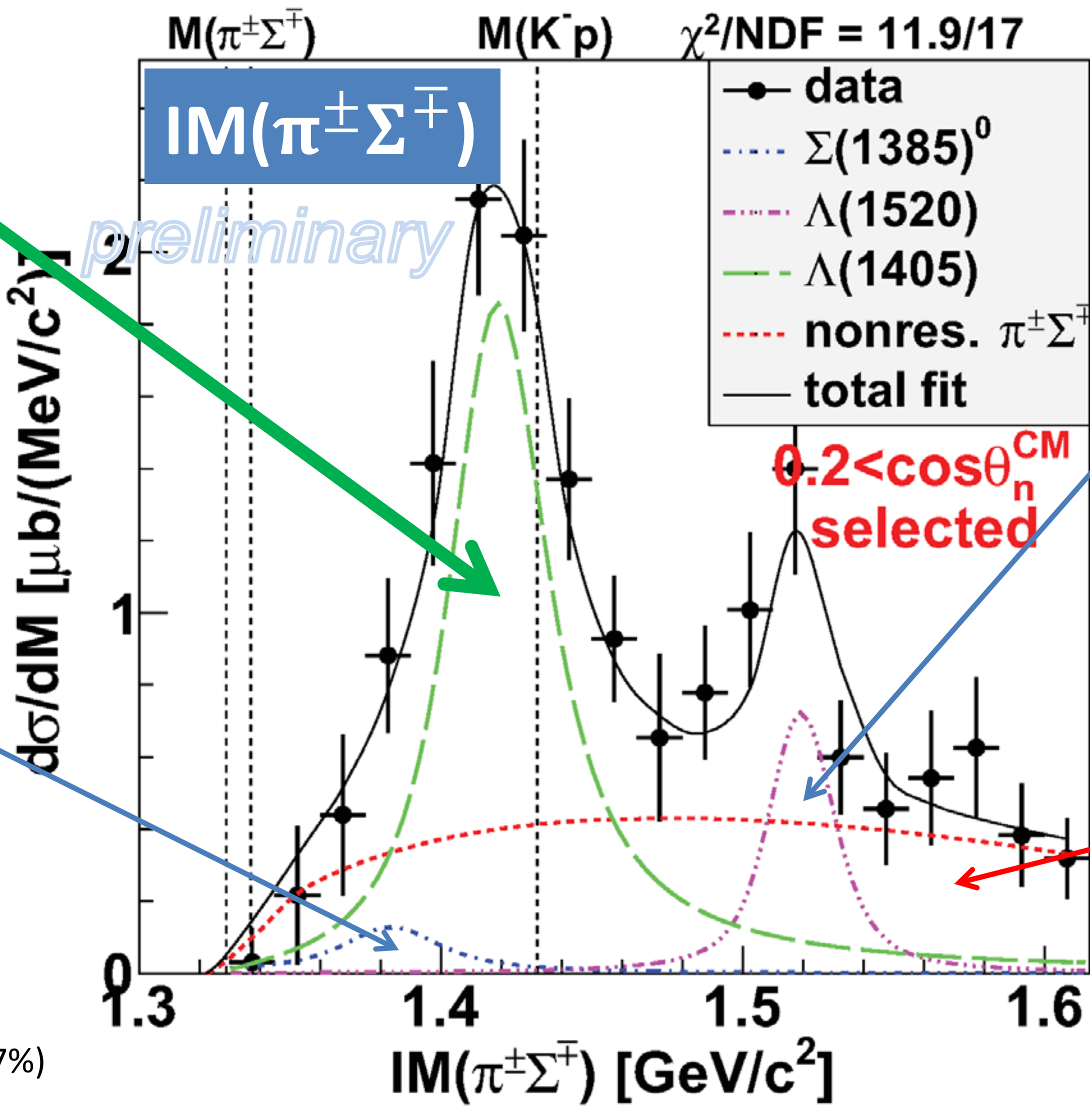
w/ Exp. BG



Λ(1405) can be clearly seen in low q_{Kn}

Y^*pn Final State *w/ simple BG subt.*

$\Lambda(1405)$
~ 150 μb
Fit w/ Flatté formula:
Re(z) ~ 1420 MeV
-Im(z) ~ 15 MeV



$\Lambda(1520)$
~ 100 μb

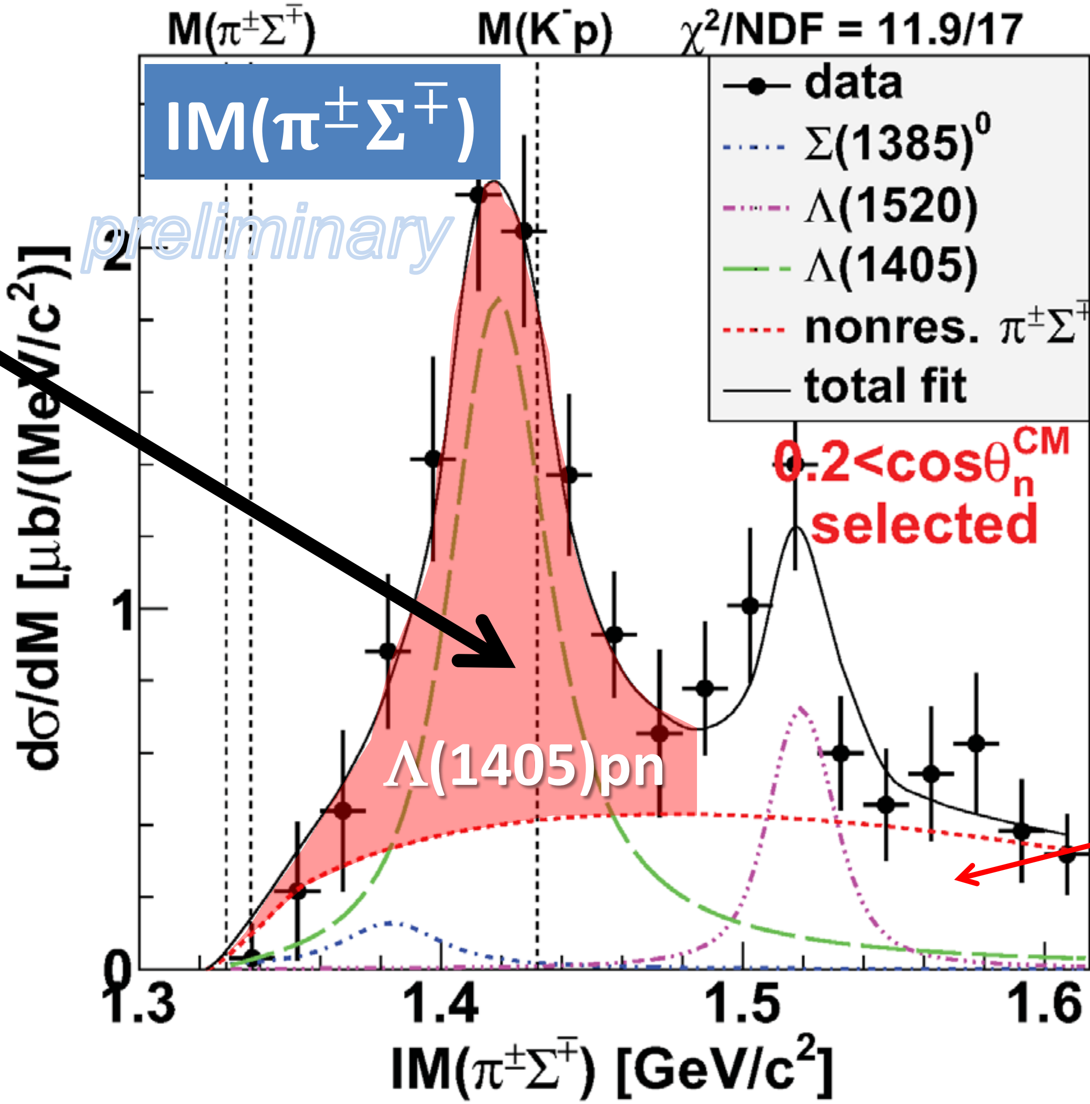
$\pi\Sigma pn$
non-resonant

$\Sigma^0(1385)$
~ 20-100 μb
[evaluated from $\Sigma^{+/-}(1385) \rightarrow \pi^{+/-}\Lambda$ measurement]
($\Sigma(1385) \rightarrow \pi\Lambda/\pi\Sigma$: 87.0/11.7%)

$\Lambda(1405)pn$ Final State Selection

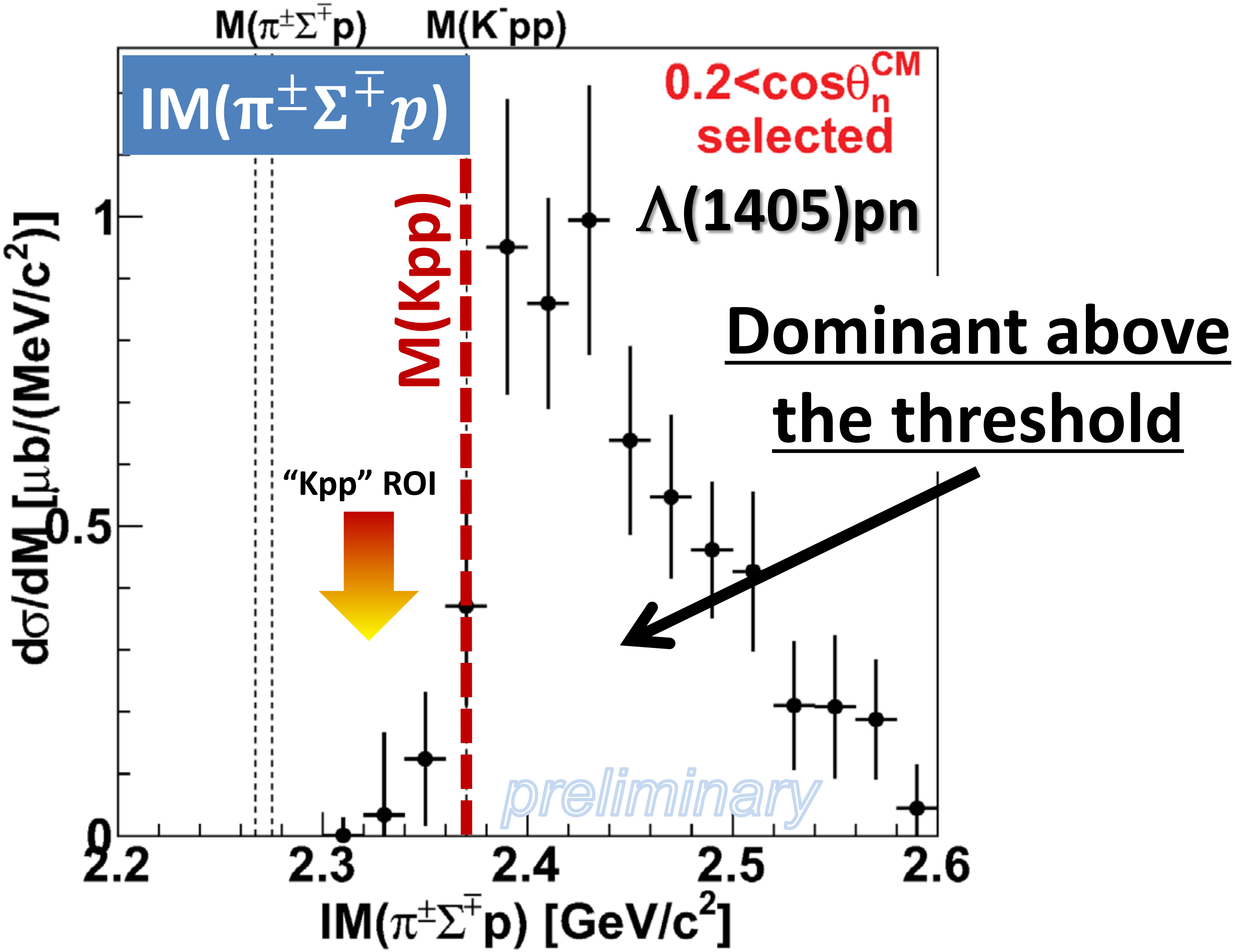
Select $\Lambda(1405)pn$ final state

- Below $\Lambda(1520)$
- Small contribution from $\Sigma(1385)$



πΣpn non-resonant

IM($\pi\Sigma$p) in Λ(1405)pn Final State

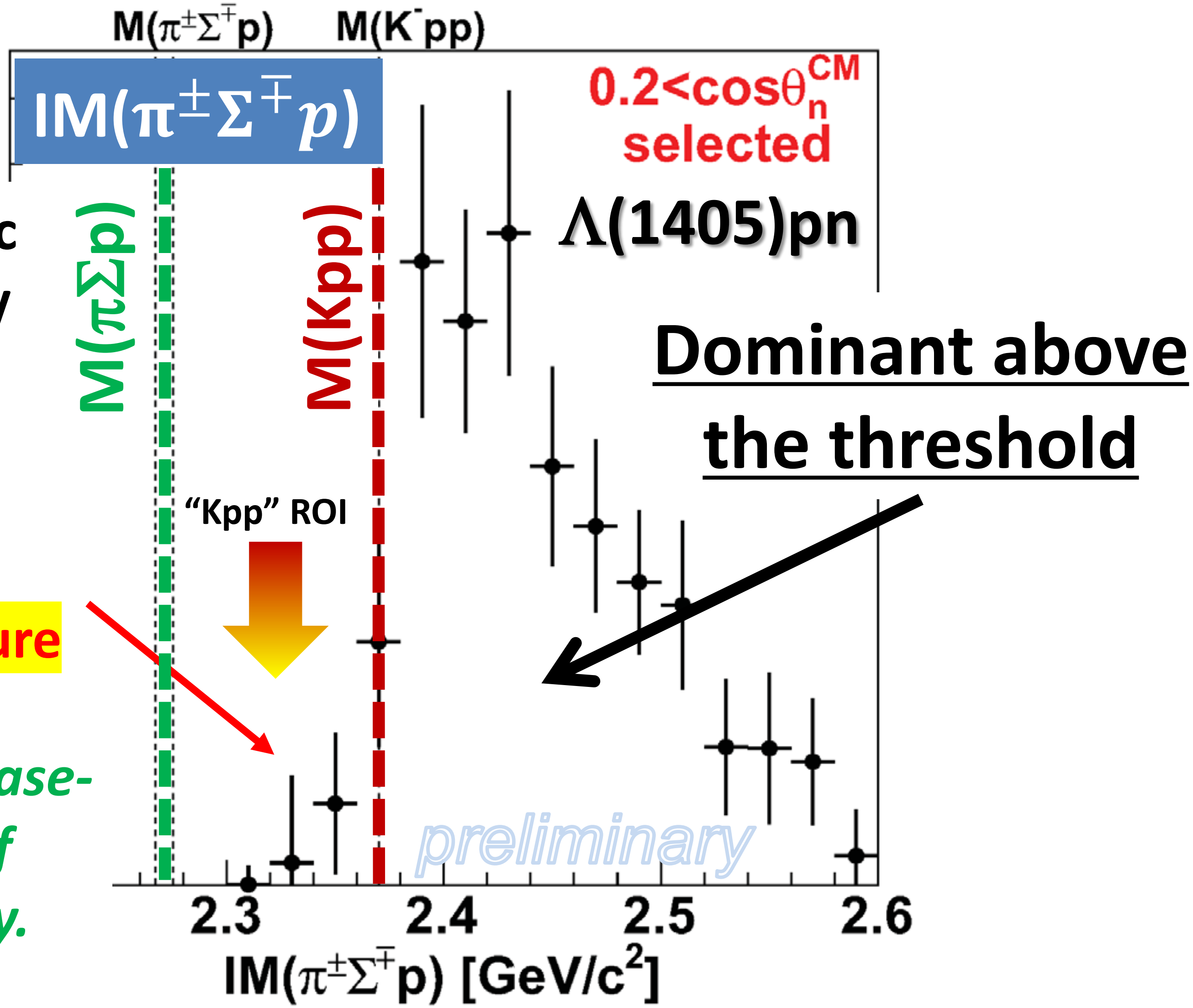


IM($\pi\Sigma$p) in Λ(1405)pn Final State

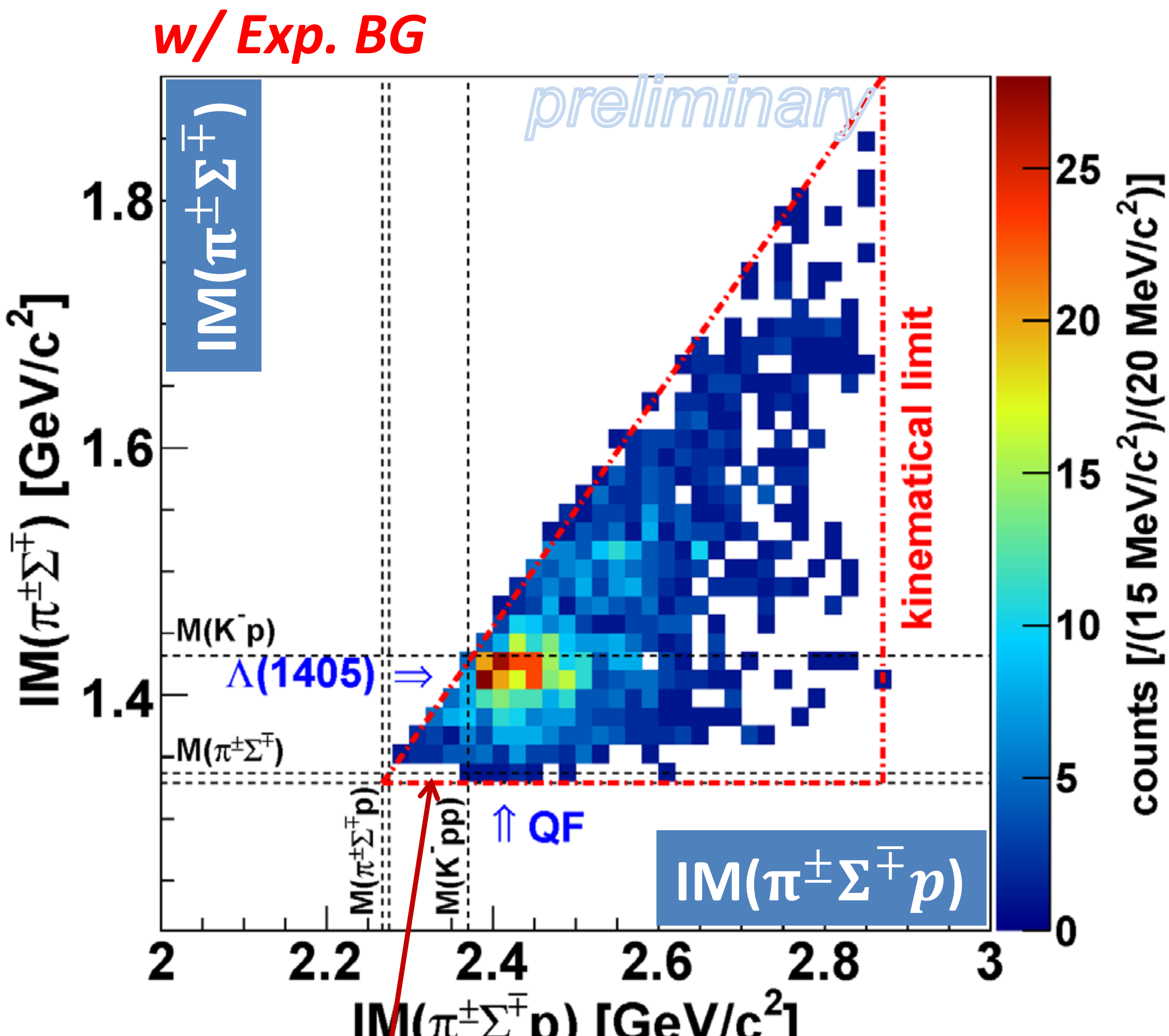
"Kpp"→$\pi\Sigma$N mesonic decay is theoretically expected to be the dominant channel

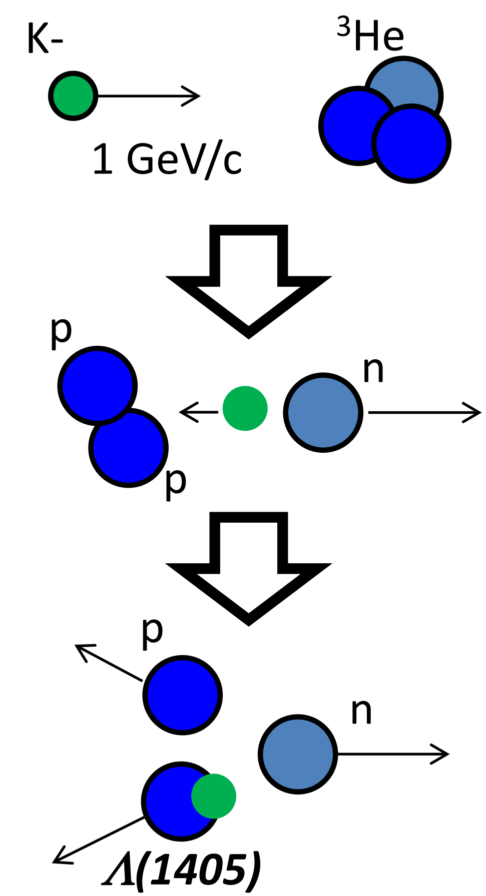
BUT, statistically, NO significant structure

This will be due to phase-space limitation of "K⁻pp"→$\pi\Sigma$N decay.



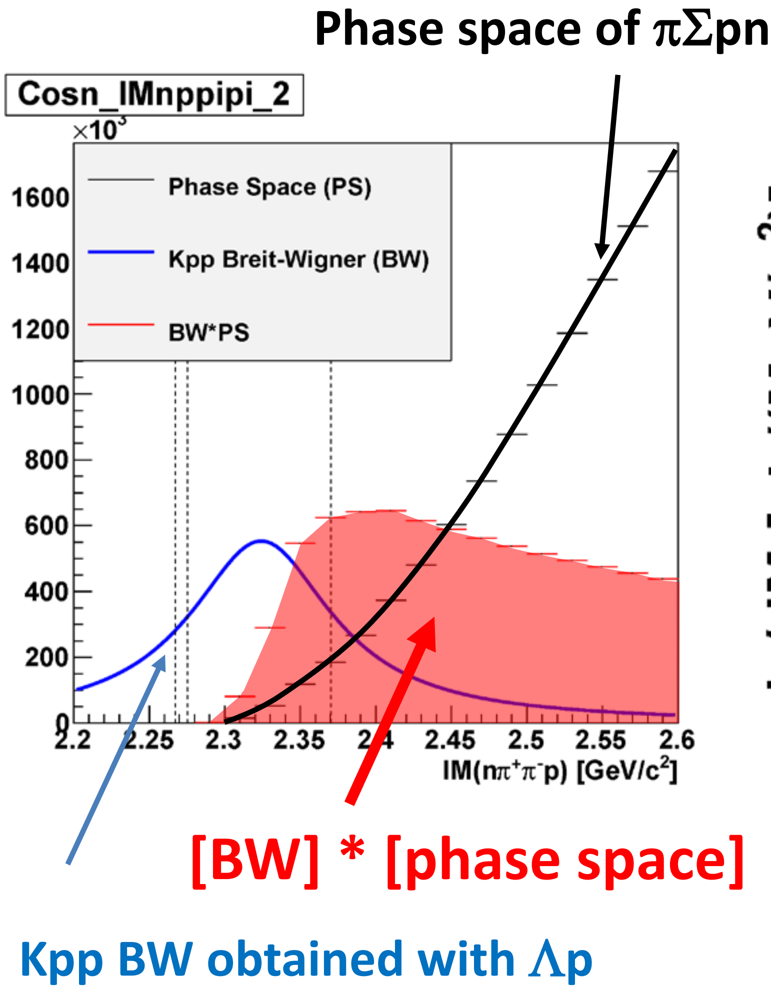
$IM(\pi^{\pm}\Sigma^{\mp})$ vs. $IM(\pi^{\pm}\Sigma^{\mp}p)$

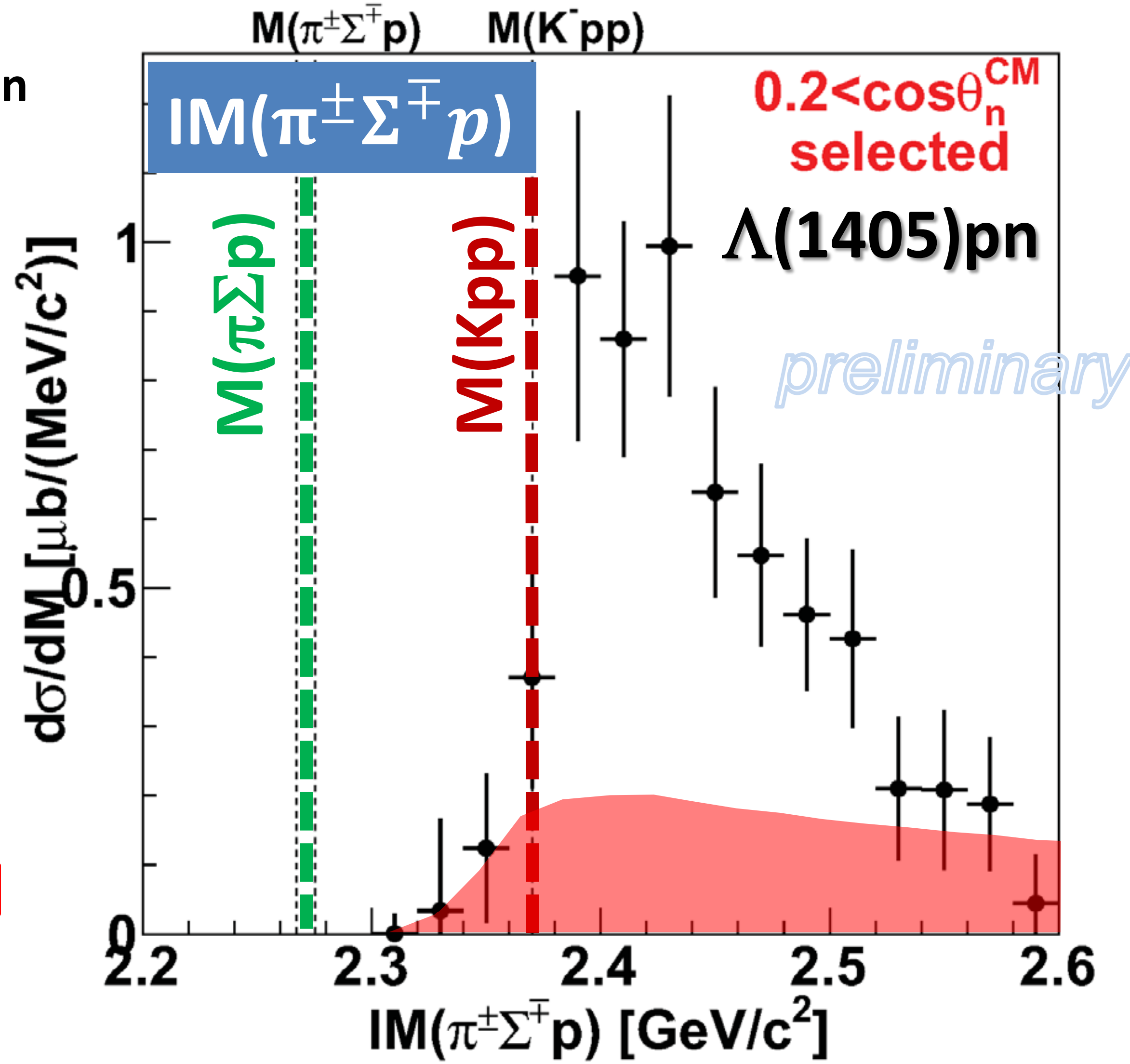




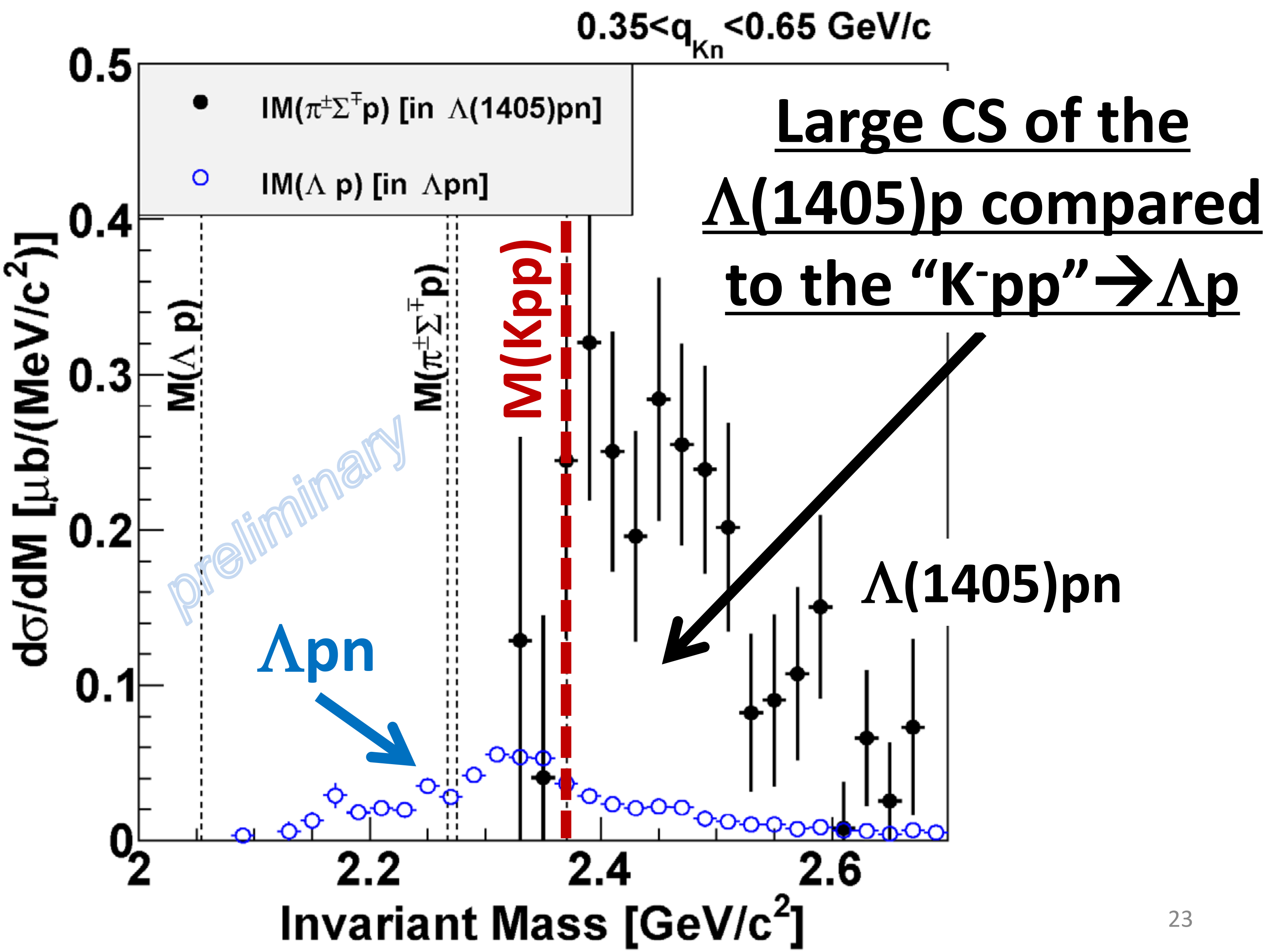
Small phase-space of "K⁻pp"→πΣN

PS Limitation of “K⁻pp”→πΣp Decay

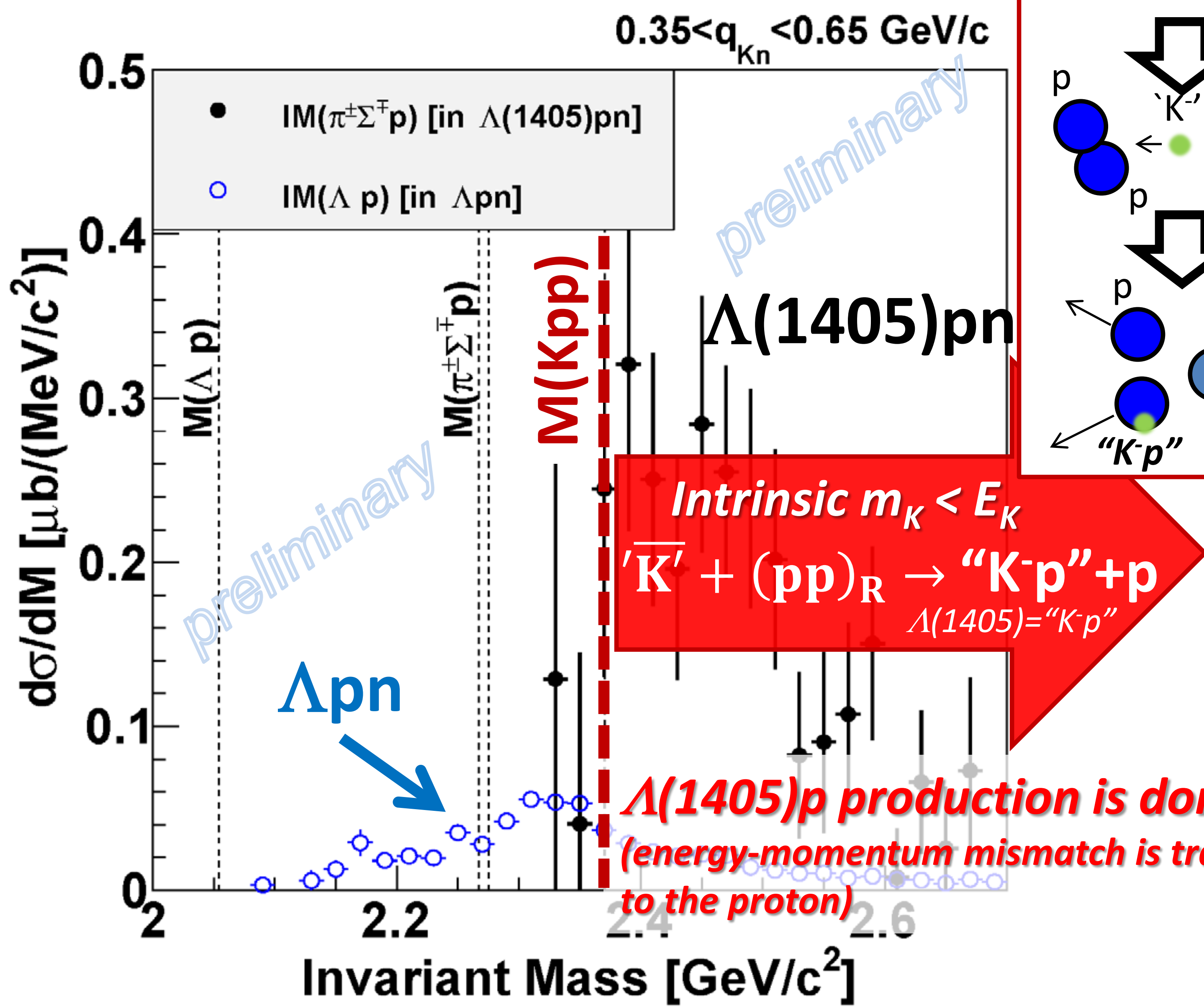


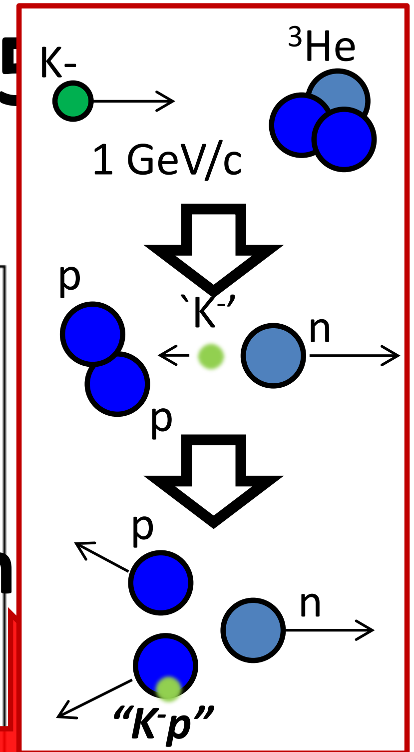


Comparison of Λpn & Λ(1405)pn



Comparison of Λpn & Λ(1405

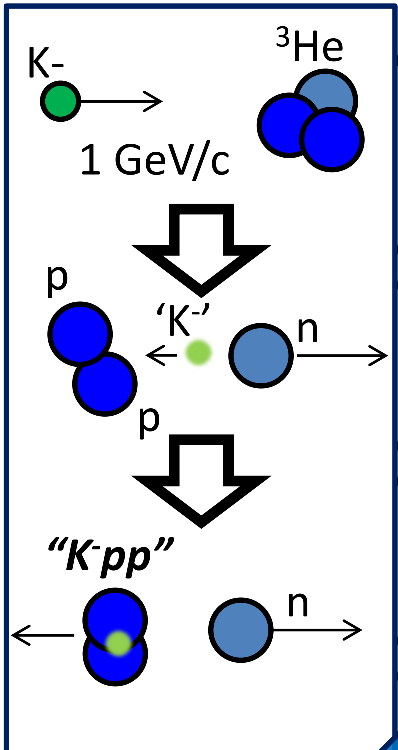


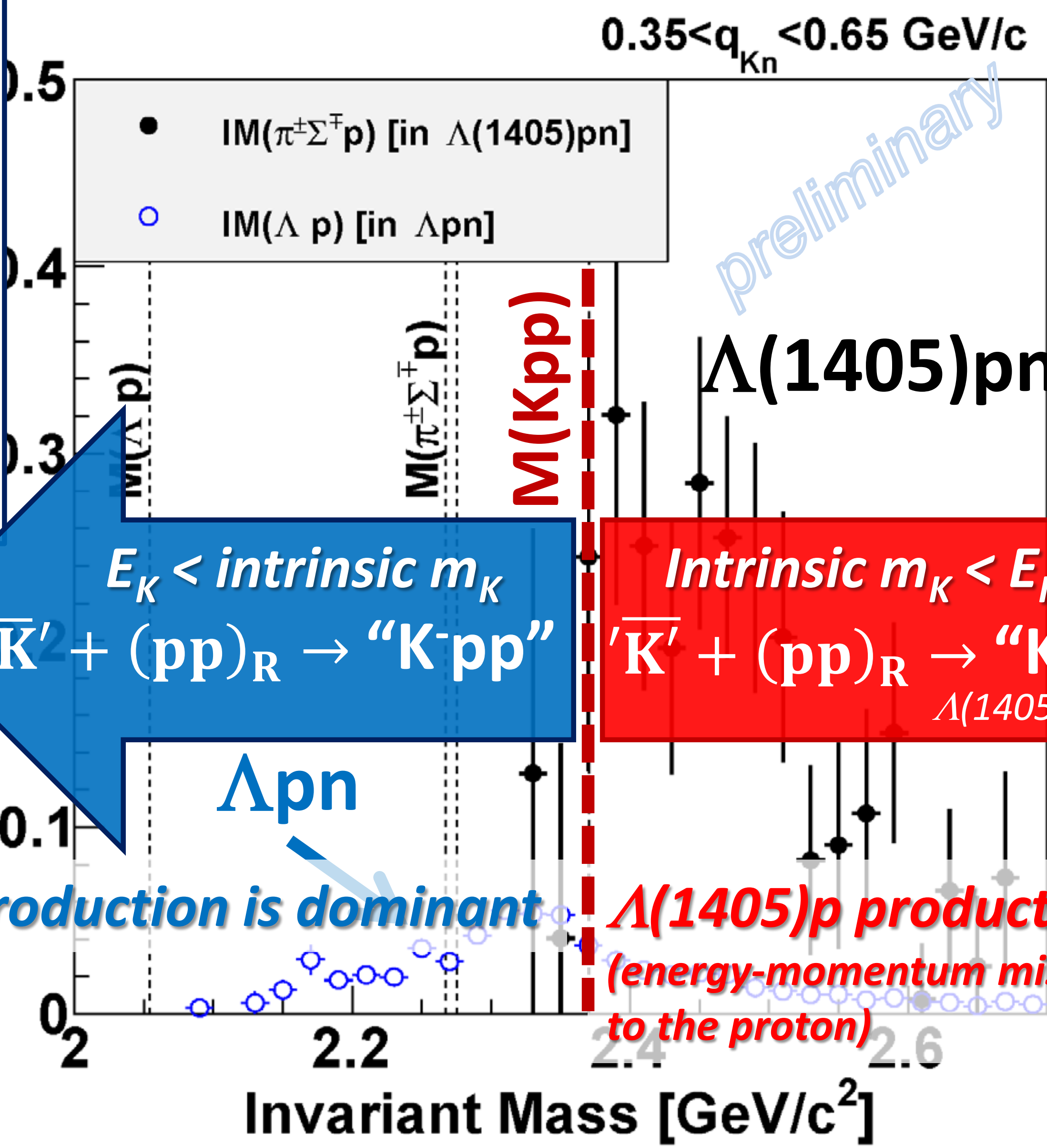


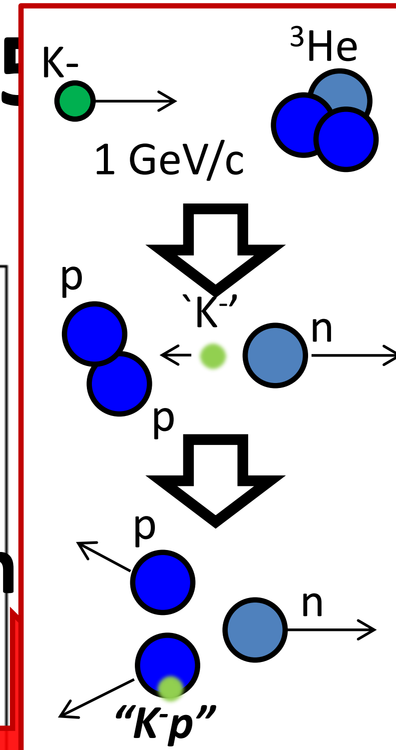
Λ(1405)p production is dominant

(energy-momentum mismatch is transferred to the proton)

…nparison of Λpn & Λ(1405…



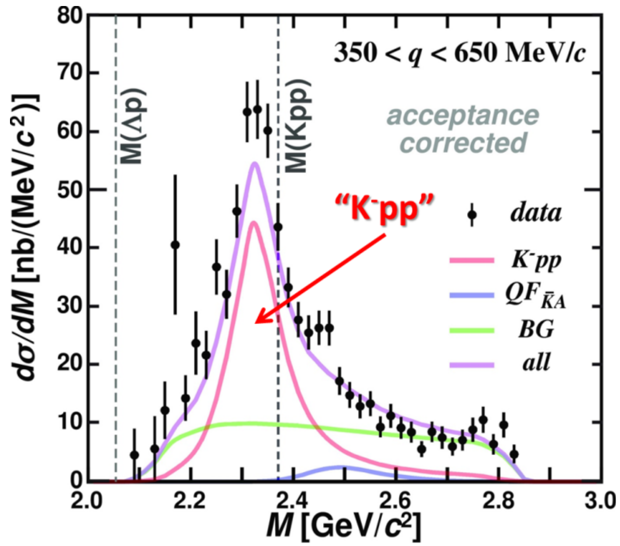




Summary

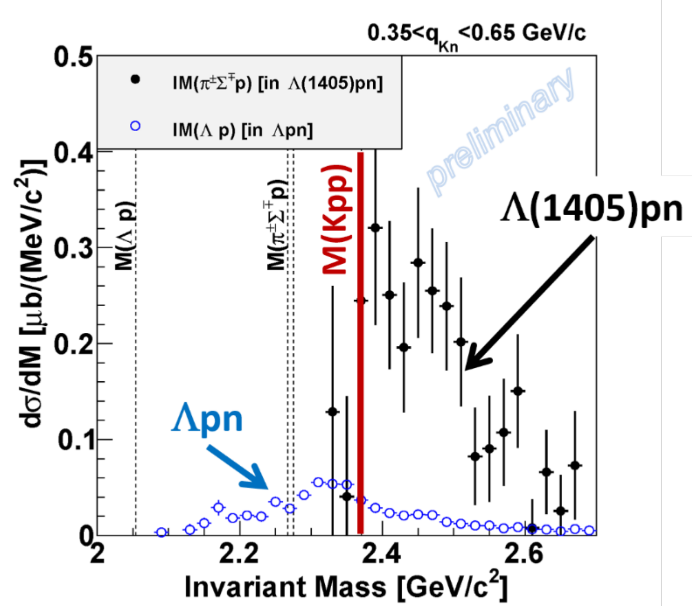
- **We observed the "K⁻pp" bound state in ^{3}He(K⁻,Λp)n**
  - Binding energy: ~50 MeV
  - Width: ~100 MeV

← PLB789(2019)620.



- **We found large CS of the Λ(1405)p formation compared to the "K⁻pp"**
  - quite important information on the production mechanism of the "K⁻pp"

← paper in preparation



Thank You!

J-PARC E15 Collaboration

S. Ajimura[a], H. Asano[n], G. Beer[b], C. Berucci[f], H. Bhang[c], M. Bragadireanu[e], P. Buehler[f], L. Busso[g,h], M. Cargnelli[f], S. Choi[c], C. Curceanu[d], S. Enomoto[o], H. Fujioka[m], Y. Fujiwara[k], T. Fukuda[l], C. Guaraldo[d], T. Hashimoto[u], R. S. Hayano[k], T. Hiraiwa[a], M. Iio[o], M. Iliescu[d], K. Inoue[a], Y. Ishiguro[j], T. Ishikawa[k], S. Ishimoto[o], K. Itahashi[n], M. Iwai[o], M. Iwasaki[m,n*], K. Kanno[k], K. Kato[j], Y. Kato[n], S. Kawasaki[i], P. Kienle[†p], H. Kou[m], Y. Ma[n], J. Marton[f], Y. Matsuda[q], Y. Mizoi[l], O. Morra[g], T. Nagae[j$], H. Noumi[a], H. Ohnishi[w], S. Okada[n], H. Outa[n], K. Piscicchia[d], Y. Sada[a], A. Sakaguchi[i], F. Sakuma[n], M. Sato[o], A. Scordo[d], M. Sekimoto[o], H. Shi[d], K. Shirotori[a], D. Sirghi[d,e], F. Sirghi[d,e], K. Suzuki[f], S. Suzuki[o], T. Suzuki[k], K. Tanida[u], H. Tatsuno[v], M. Tokuda[m], D. Tomono[a], A. Toyoda[o], K. Tsukada[r], O. Vazquez Doce[d,p], E. Widmann[f], T. Yamaga[n], T. Yamazaki[k,n], H. Yim[t], Q. Zhang[n], and J. Zmeskal[f]

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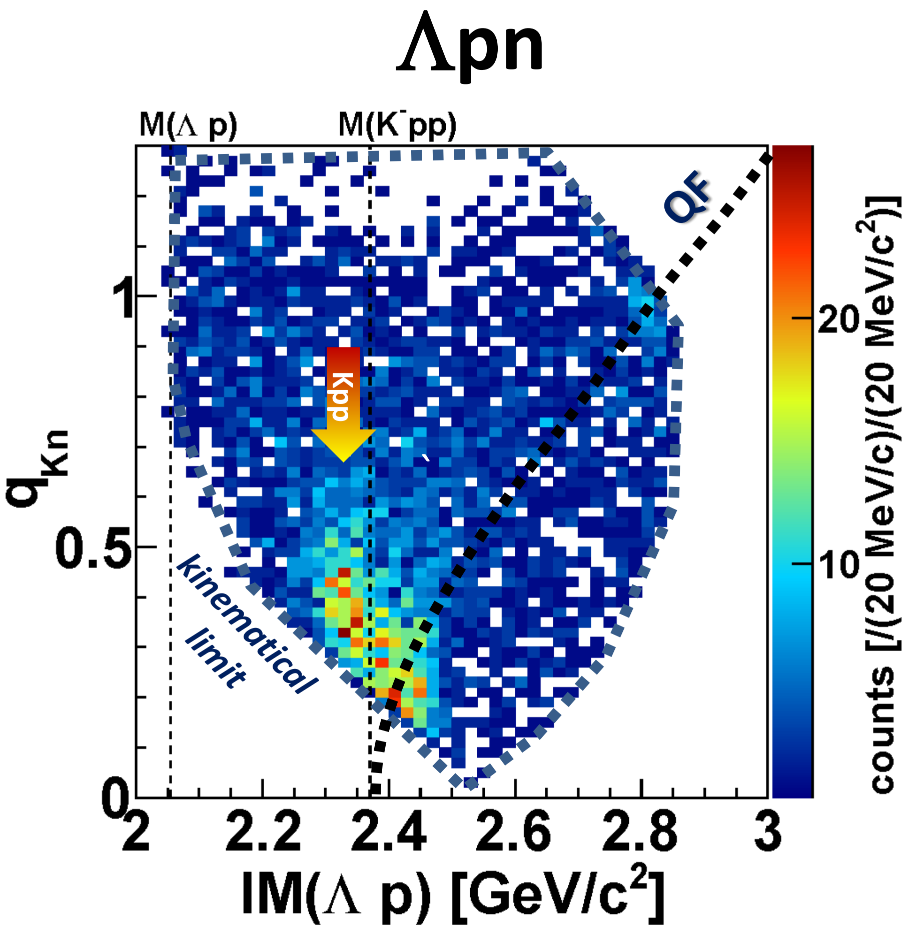
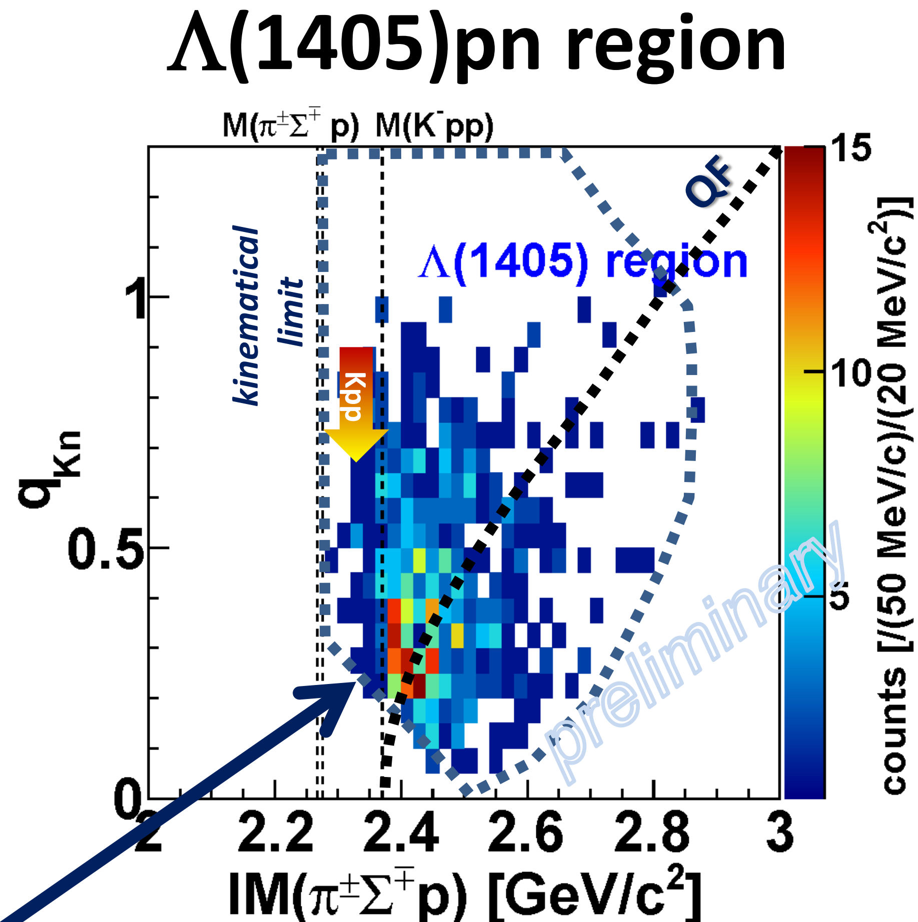
Spares

Comparison of Λpn & Λ(1405)pn

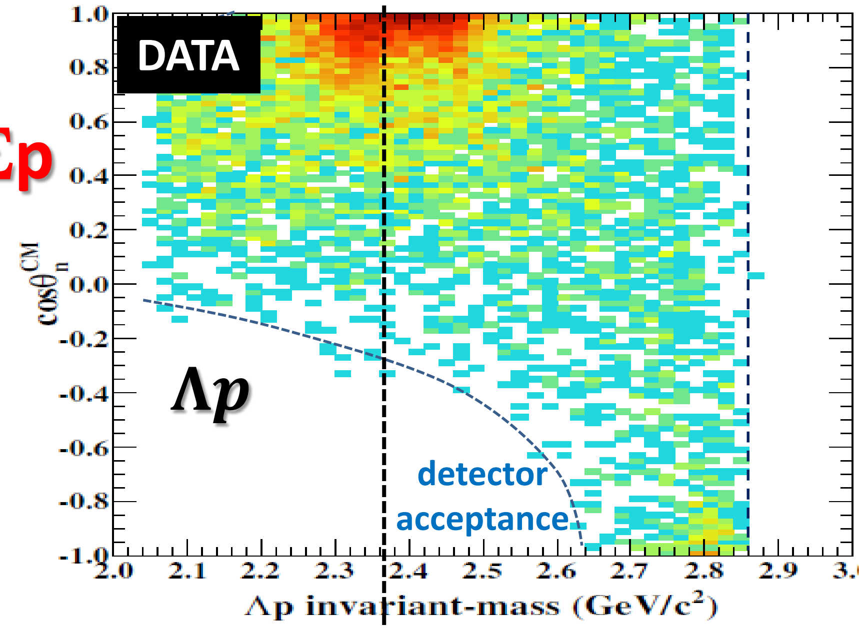


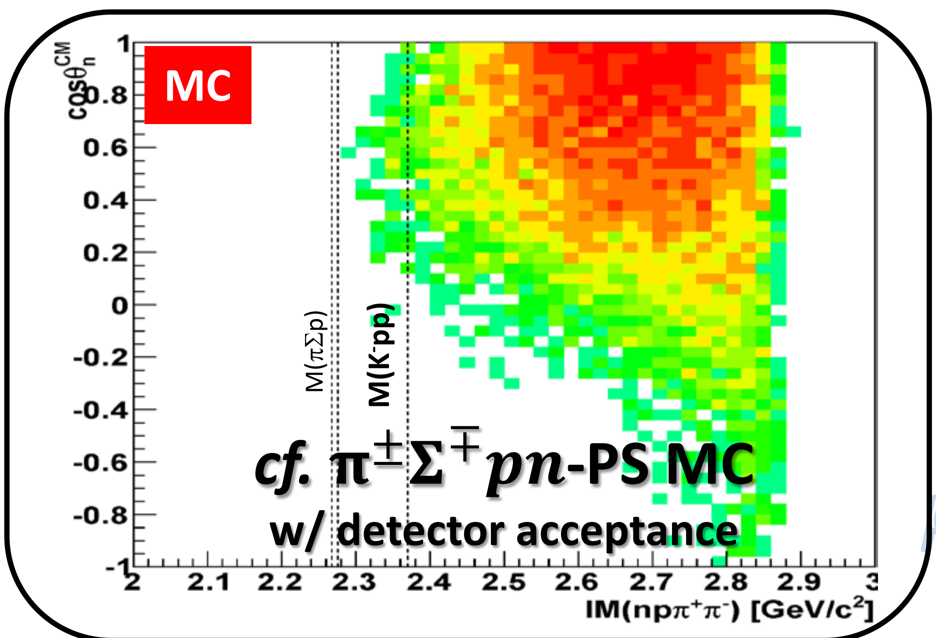


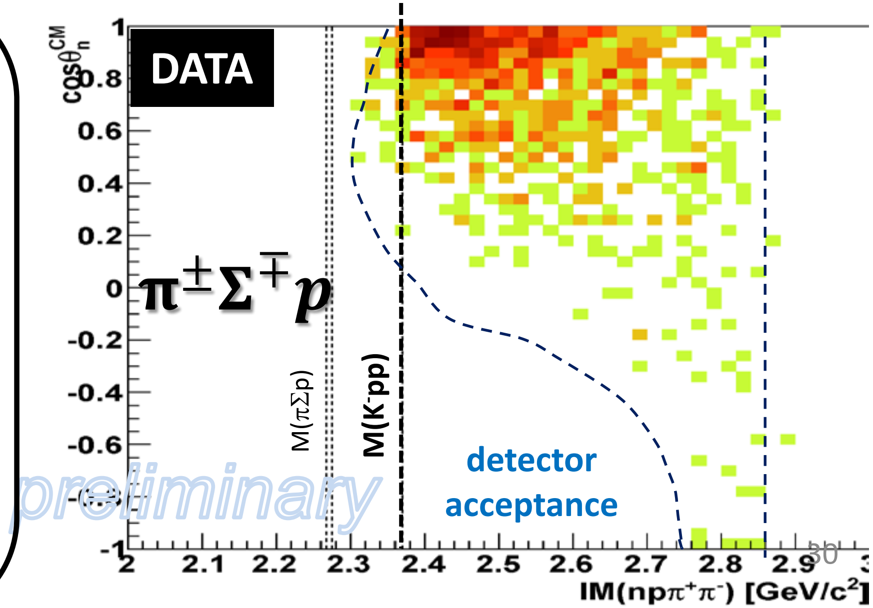
- **No clear structure below M(Kpp) in the IM($\pi\Sigma$p)**
- **QF followed by Λ(1405)p is dominant**

Detector Acceptance: Λp vs. πΣp

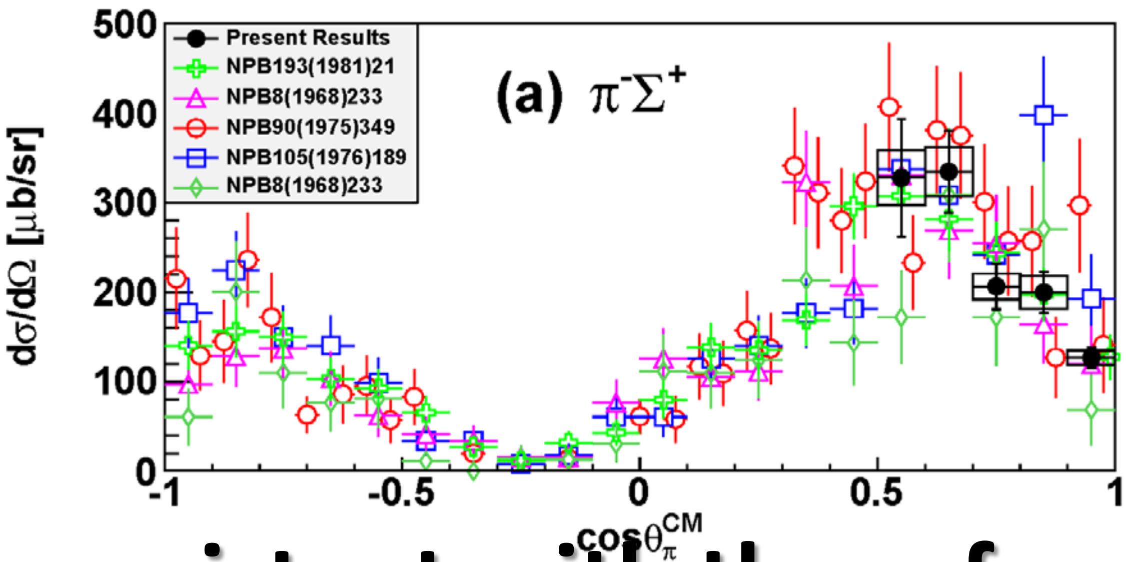
- **Detector acceptance is different between Λp and πΣp**
  - At $\cos\theta_n$~1:
    - Λp: flat acceptance
    - πΣp: limited acceptance below the threshold



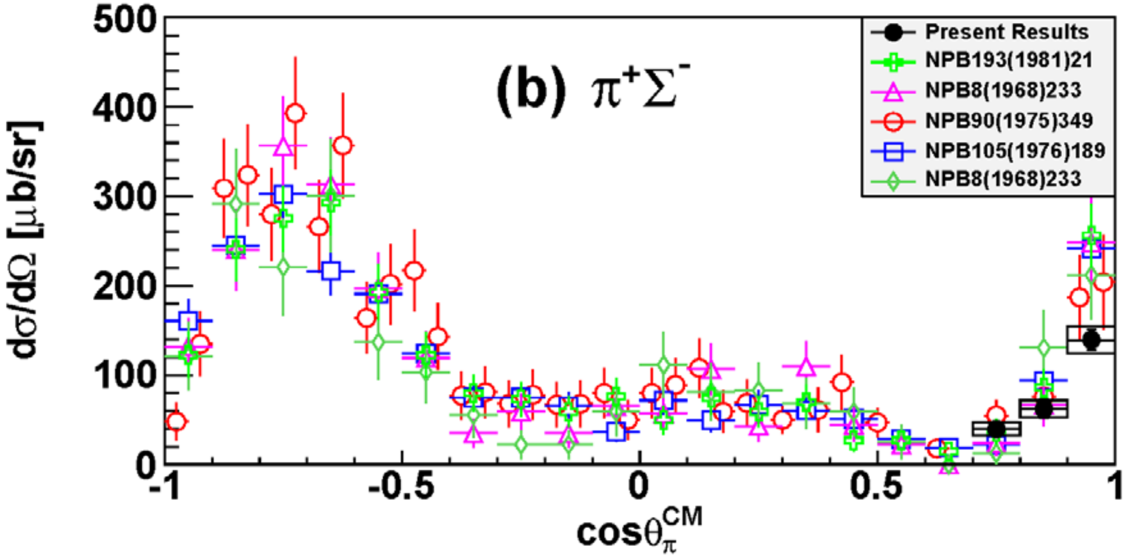




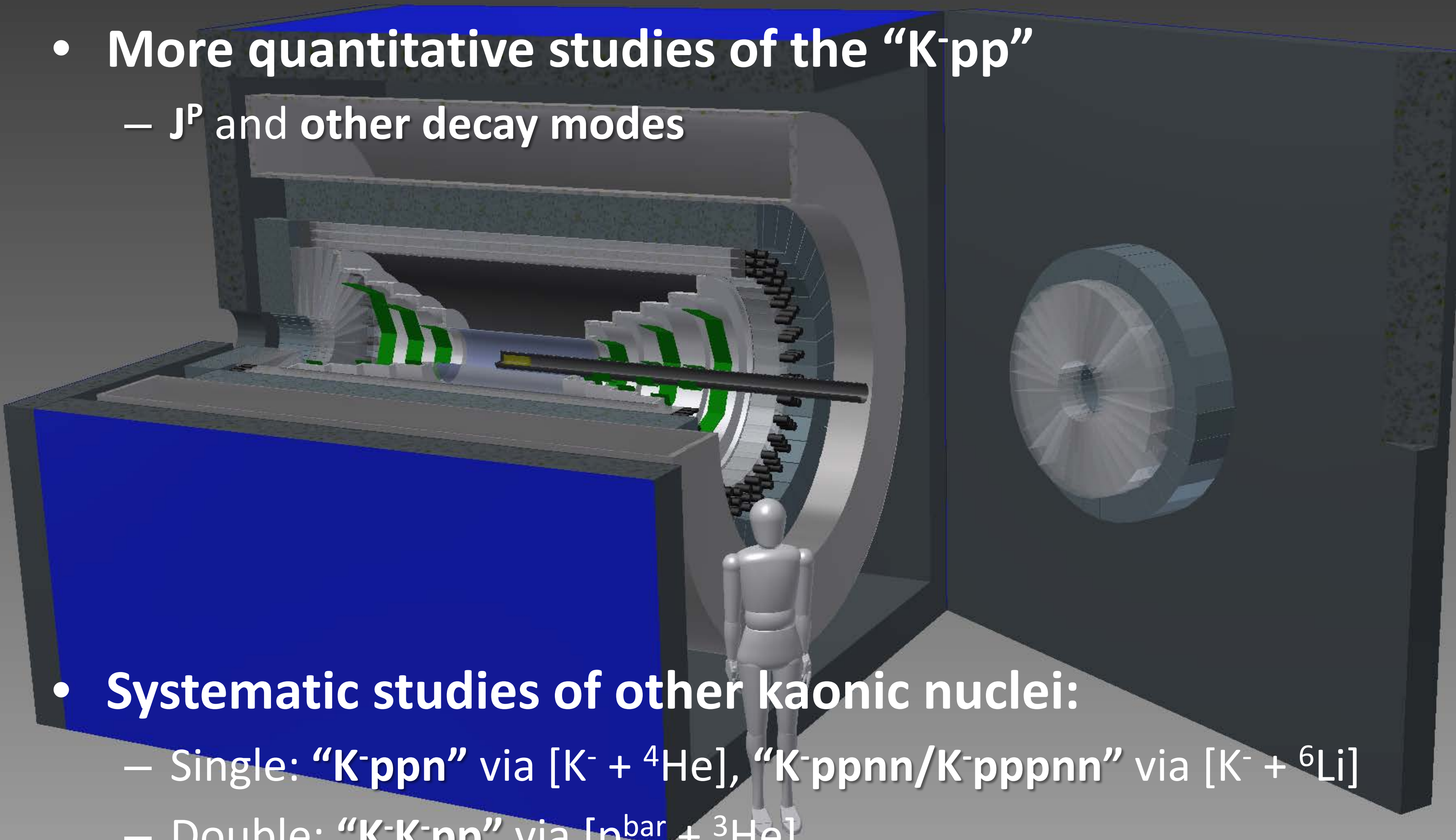
$K^-p \rightarrow \Sigma^+\pi^-/\Sigma^-\pi^+$ Cross Section



consistent with the references



Need further investigation



- **More quantitative studies of the “K^-pp”**
  - **J^P** and **other decay modes**
- **Systematic studies of other kaonic nuclei:**
  - Single: **“K^-ppn”** via [K^- + ^{4}He], **“K^-ppnn/K^-pppnn”** via [K^- + ^{6}Li]
  - Double: **“K^-K^-pp”** via [p^{bar} + ^{3}He]

A new 4π detector with γ/n sensitive detectors is required